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## ORIGINAL ARTICLES.

### I.—On a New Specimen of *Histionotus angularis*, Egerton.

By J. C. Mansel-Pleydell, F.L.S., F.G.S.

(PLATE VII.)

*Histionotus angularis*, was first described and figured by the late Sir Philip de M. Grey Egerton, Bart., F.R.S., in Decade viii. of the Memoirs of the Geological Survey, 1853. The uninterrupted dorsal fin, extending from near the occiput to the tail, suggested the generic name of *Histionotus*,[1] and in this feature it re-resembles *Ophiopsis*. It has the characters also of other genera, for instance, *Pholidophorus* in its scales, *Semionotus* in the shape of its body, and *Lepidotus* in the shape of its head. Sir Philip Egerton, misled by the imperfect preservation of the posterior end of his specimen, thought the caudal-fin to be also similar to that of *Lepidotus*. By a singular coincidence, a fine specimen of *Lepidotus minor* lies side by side on the same slab with the subject of this note (Pl. VII.), and the caudal fin of each is well exposed, showing that of *Lepidotus* to be comparatively short and truncate, while that of *Histionotus* is deeply forked. In its crushed condition, the upper lobe in *Histionotus* is longer and larger than the lower lobe; but this is proved to be a deceptive appearance by another example of the genus I have since met with from the same quarry which displays the symmetry of the tail-fin, the lobes being beautifully shown of equal length.

The outline of the upper portion of the body is triangular, rising abruptly from the snout to a distance of 20 millim. beyond the base of the occiput along the dorsal ridge, and then descending by a less abrupt gradient from this culminating point to the base of the caudal fin, a distance of 85 millim. The depth of the body at the most elevated part of the dorsal ridge to the pectoral fin is 65 mm., to the shoulder-girdle 33 mm.

The anterior margin of the first ray of the dorsal fin, which is stouter than the others, is furnished with a series of fulcral rays. The remaining rays, of which there are more than twenty, bifurcate about half-way from the base, and the distal halves are again bifurcated and cleft. The pectoral fin consists of seven rays, of which the first is the longest and stoutest, and all are bifurcate

[1] ἱστίος, a sail, νῶτος, a back.

and split. Each ventral fin, which is 20 mm. long, has only four rays, the first exceedingly stout and furnished with a series of large marginal fulcra; and all the rays are transversely articulated or jointed beyond the point of bifurcation. The anal fin has four rays also, and is the smallest of all; the length of the largest ray being 15 mm. The caudal fin consists of eight rays in each lobe, the upper lobe appearing 40 mm. long, whereas the lower is only 25 mm. The margins of the upper ray of the larger lobe and of the lower ray of the smaller are furnished with a series of large fulcra which probably increased the locomotive power of the tail.

The depth of the shoulder-girdle is 25 mm., and the breadth of the post-clavicular plates (*p. cl.*) 5 mm. The opercular apparatus is well preserved, showing distinctly the operculum (*op.*), suboperculum (*s. op.*), interoperculum (*i. op.*), and preoperculum (*p. op.*), besides a few branchiostegal rays (*br.*). These, like the post-clavicular plates of the shoulder-girdle, are all enamelled.

The bones of the head are much crushed. The maxillæ, although perfect, are displaced; and a portion of the right premaxilla is preserved, showing seven teeth, with part of the eighth. These teeth are styliform, slender, straight, and smooth, and appear to decrease in size from front to back. The largest is 2 mm. in length. The vomerine bones are hidden, which unfortunately prevents our ascertaining whether or not the roof of the mouth is armed with teeth. The orbit is obliterated by the intrusion of the underlying skull-bones.

The scales of the body are small as compared with those of *Lepidotus*, and are not so lustrous. Those of the flank measure 6 mm. in depth and 2 mm. in breadth. They are rhomboidal in shape, finely pectinated on the posterior exposed margin, arranged obliquely in rows from the dorsal to the ventral region, twelve in a series. The lateral line from head to tail extends along the middle of the flank. Between the last ray of the dorsal fin and the base of the caudal, are three double-cone-shaped lustrous ridge-scales, which may have served to strengthen this attenuated part of the body, enabling it to resist the strain upon it when the caudal fin was in action.

| | |
|---|---|
| Length of body ... ... ... ... ... ... ... ... ... | 1·80 m. |
| ,, tail, upper lobe ... ... ... ... ... ... ... | 0·50 m. |
| ,, ,, lower lobe ... ... ... ... ... ... ... | 0·30 m. |
| ,, head ... ... ... ... ... ... ... ... ... | 0·46 m. |
| Breadth of head ... ... ... ... ... ... ... ... ... | 0·40 m. |

## EXPLANATION OF PLATE VII.

*Histionotus angularis*, Egerton; right lateral aspect of fish, nat. size. Middle Purbeck Beds, Swanage, Dorsetshire. *br.* branchiostegal rays. *i. op.* interoperculum. *op.* operculum. *p. cl.* post-clavicular plates. *p. op.* preoperculum. *s. op.* suboperculum.

The specimen from which the above description is taken, and which is figured in the accompanying plate, was procured by me from a quarry at Herston, near Swanage, Middle Purbeck. It is now preserved in the Dorset County Museum, Dorchester.

Whatcombe, Blandford, Dorsetshire.

## II.—On Statical and Dynamical Metamorphism.

By Prof. John W. Judd, F.R.S.

It has long been recognized by geologists that rock-masses which have undergone movement, and have thereby been subjected to internal stresses, exhibit, as the consequence of the action upon them of such mechanical forces, unmistakeable evidences of having been greatly modified, alike in their mineralogical and in their structural characters. That the most complete and striking examples of such changes are to be found in the rock-masses which constitute mountain-chains—rock-masses which have actually been made to "flow," and in so doing have been subjected to shearing movements of the most intense character—was clearly pointed out by Scrope, Darwin, Sharpe, Naumann, and Dana; all of whom referred the foliated structure exhibited by such rock-masses to this cause.

The careful study, in recent years, of the actual processes involved in bringing about such changes, has rendered necessary the adoption of certain terms, to define the nature of the action in particular cases. In 1869, Lossen proposed to call the changes produced during rock-movements "dislocation-metamorphism" (dislocationsmetamorphismus);[1] while four year later Baltzer invented the term "mechanical metamorphism" (mechanischer metamorphismus);[2] in 1884 Gosselet suggested the term "friction-metamorphism" (métamorphisme par friction);[3] and in the following year Gümbel employed the name "compression-metamorphism" (stauungsmetamorphose);[4] while in 1886 Bonney proposed to use the term "pressure-metamorphism."[5]

Rosenbusch, in the same year, seeking to bring clearly into view the consideration that the special kind of metamorphism referred to is only produced when the mechanical forces effect movement, and thus do work, suggested the term *Dynamical metamorphism* or *dynamometamorphism*;[6] and this term, if not absolutely free from objections, is so convenient that it bids fair to be generally adopted.

There is perhaps at the present time a tendency to exaggerate the results of this particular agency of dynamical metamorphism, and to overlook or minimize the importance of other contributory causes to the alteration of rock-masses. I desire in this note to call especial attention to the remarkable effects which result from the chemical and crystallizing processes which certainly go on at great depths, and under enormous pressures, *even when the rock-masses do not yield to the pressures* and thus become subjected to the movements which

[1] Zeitschr. d. d. geol. Gesellsch. Bd. xxi. pp. 282–340.
[2] Der Glärnisch (1873), p. 58.
[3] Ann. Soc. Géol. du Nord, xi. (1884), p. 188.
[4] Geol. von Bayern, i. p. 379.
[5] Ann. Address Geol. Soc. Q.J.G.S. vol. xlii. (1886), p. 62.
[6] Der Massige Gesteine, 2nd ed. 1886.

result in dynamometamorphic action. Such changes, resulting from pressures that do not effect movements in the rock-masses, may be appropriately called "statical metamorphism."

The researches of modern physicists are beginning to enable us to realize what are the chief factors in these processes which go on at great depths within the earth's crust. The striking experiments of Guthrie have shown that there is a perfect gradation between the states of fusion and solution, and have enabled us to realise the important part played by even small quantities of water or other liquids held under great pressure in the deeper and highly heated masses of the earth's interior.[1] The researches of Spring, van't Hoff, Reicher, and others have shown the effects of pressure in bringing the molecules of solid bodies sufficiently close to one another for chemical affinity to operate between them; and especially significant to the geologist is a recent conclusion arrived at by the first-mentioned physicist, that when the particles of a solid are brought into juxtaposition by the action of mechanical force, the chemical processes may go on even after the pressure is removed. Time, it is thus shown, may become an important factor in such changes.[2] And, lastly, Van der Waals in his remarkable essay on "The Continuity of the Gaseous and Fluid States" has shown that "*all bodies can mix with one another when the pressure exceeds a certain value.*"[3]

That at great depths and under the enormous pressures within the earth's crust, *the whole substance* of solid rocks—crystallized minerals and glassy groundmass alike—may be traversed by various liquids and gases, I think it is impossible to doubt. In various papers in which I have endeavoured to establish and illustrate the theory of "Schillerization,"[4] I have shown that rocks, which at any point of their history have been deep-seated, have undergone very remarkable changes—their minerals having been metamorphosed and transformed, and their original structure sometimes completely altered; these changes, which have taken place quite independently of any movement that the rock-masses may have been subjected to, can therefore be spoken of as *statical* metamorphism. A striking illustration of the truth of the conclusions arrived at by Van der Waals is afforded by the fact, that in the interior of rock-forming crystals, we find cavities (indisputably formed by solvent action long subsequently to the formation of the minerals themselves), containing at the same time, various supersaturated aqueous solutions and also carbon-dioxide retained in the liquid condition by pressure.

It may be of interest at the present time to draw a comparison

[1] The bearings of Dr. Guthrie's researches on geological problems have been already pointed out. See this MAGAZINE, Dec. III. Vol. V. p. 1, 1888.

[2] Amer. Journ. Sc. 3rd ser. vol. xxxvi. (1888), p. 288.

[3] I am indebted to my colleague Prof. Rücker, F.R.S., for calling my attention to the valuable researches of Van der Waals, which have had such an important influence on the views of physicists. His essay, which was translated from the original Dutch into German in 1881, is now about to be issued in English form by the Physical Society.

[4] Quart. Journ. Geol. Soc. vol. xli. (1885), pp. 374–389; Mineralogical Magazine, vol. vii. (1886), p. 81.

between the effects of statical and dynamical metamorphism respectively.

Setting aside the more purely mechanical effects which may precede or accompany dynamical metamorphism—such as cleavage, jointing, the crushing or deformation of included fragments, the stretching of rocks, and the production of "mylonitic" bands—the results of this agency may be classified as follows:—

*First.*—The inducement of metamorphoses in the constituent minerals of a rock. That minerals are capable, without losing their identity, of undergoing remarkable metamorphoses, whereby their chemical, crystallographical, optical and other physical properties may be modified within certain—though often indeed very wide—limits, is now beginning to be recognized by both mineralogists and geologists. The production of twin-lamellation in many minerals by internal and external stresses, and the deformation of crystals by these means, so that they assume not only the external angles, but the internal structure and the optical properties of complex twins belonging to a system of lower symmetry than their own, are now well-recognized facts. An admirable illustration of this action is afforded by the production of microcline from orthoclase. The beautiful experiments of Des Cloizeaux, Dufet and Bücking on this same mineral species, orthoclase, have shown that both by heating and by pressure the position of the optic-axial plane, and the angle between the axes may undergo temporary changes; while, if the temperature or pressure pass beyond a certain limit, these changes become permanent. The study of the minerals of the enstatite-group has shown that as certain chemical changes go on within their crystals, these, while retaining their orthorhombic symmetry, may undergo the most remarkable modifications, not only in their colour, pleochroism, and absorption, but also in their index of refraction, in the sign and intensity of their double refraction, in the position of their optic-axial plane and in the angle between their axes; and further, that, changes in specific gravity, in hardness and in fusibility may accompany these several modifications.

That the form and position of the ellipsoid of elasticity in a crystal may be altered temporarily and even permanently by the action of heat, pressure, or chemical agencies, is a phenomenon for which we ought to be fully prepared; and it is upon the form and position of this ellipsoid that the so-called optical "constants" of a mineral depend.

That the metamorphoses which have been more or less fully investigated in the case of a few species, like orthoclase, enstatite, selenite, etc., are not confined to those species must be clear to all who have been in the habit of studying the so-called "optical anomalies" of minerals; and such "anomalies" are especially frequent in the case of the common rock-forming species. When we remember the nature of the forces to which the constituent minerals of rocks must have necessarily been subjected in many cases, we shall cease to wonder at this result.

*Secondly.* As there must be, in every case, a limit beyond which a

mineral cannot change without losing its identity, the final result of the internal stresses set up in a rock-mass is that the constituent minerals are gradually transformed into totally different ones. This transformation may take place in two different ways:—First, *paramorphic*, or change into a new mineral species crystallizing in the same or a different system, but having the same chemical composition; or secondly, *metachemic* (to use Dana's convenient term)[1] when, in consequence of the addition or subtraction of materials, or of both of those processes combined, the chemical composition as well as the crystallographical characters of the substance undergoes complete alteration.

*Thirdly.*—This change in the mineralogical constitution of a rock may be accompanied by a modification, more or less complete, in its structure. The structures which usually result from the action of *dynamical* metamorphism are the *granulitic*, and the *foliated* or *schistose*. It must be remembered that while these changes in structure may undoubtedly take place in rock-masses which have long since acquired the solid condition, they are also liable to arise in masses which are still in a plastic or viscous condition, and as the result of a primary rather than of a secondary crystallization when the mass is under the influence of internal stresses and movements. I have shown how completely the granulitic structure may be developed on the sides of great intrusive masses of gabbro; and General McMahon has well illustrated the production of foliation in intrusive granite-veins. Even in hypocrystalline rocks, like the more acid lavas, as Scrope and Darwin so admirably proved, the shearing movements in a slowly moving, viscous mass give rise to phenomena having the most striking resemblance to the foliation of the crystalline schists.

Let us now direct our attention to the class of changes which take place in rocks which are subjected to great pressure, but in which this pressure has not produced differential movement resulting in shearing. In these cases the most potent agency by which change is effected consists in the penetration of the whole mass of the rock by various liquid or gaseous solvents. It is for the whole group of such changes—of which "schillerization" is a conspicuous example—that I propose to employ the term *statical* metamorphism. Such statical metamorphism can often be shown to have taken place in the same rock-masses which have undergone dynamical metamorphism—the statical metamorphism either preceding or following the dynamical metamorphism.

The effects of statical metamorphism may be conveniently classed under the same three headings which we have employed in considering the results which are produced by dynamical metamorphism.

*First.*—The metamorphoses of the constituent minerals in a rock. We cannot perhaps better illustrate the nature and variety of the changes which take place in minerals subjected to great pressures

[1] Amer. Journ. Sci. (1886), vol. xxxii. p. 69–71.

than by referring again to the very widely distributed species orthoclase. This mineral, according as it has been formed near the surface or at great depths, assumes the special crystallographic habit, the lustre, density and other properties which characterize *sanidine* and *adularia* respectively. But, subsequently to their formation, the crystals may have their optical characters completely altered either by heat or pressure, so that the position of the optic-axial plane and the angle between the axes change to those of *anomalous orthoclase* (orthose deformé). On the other hand, the great mechanical stresses, to which rock-forming orthoclases have in some cases been subjected, has frequently caused them to assume the external angles, the internal structure and the optical properties characteristic of *microcline*.

But there are a number of other changes that orthoclase-crystals are subject to, which, though they have certainly been produced only in crystals that have existed in deep-seated rock-masses, yet cannot be referred to any process of dynamic metamorphism.

Almost universally, the crystals of orthoclase in such deep-seated rock-masses are found to have lost their transparency and vitreous lustre, and to have acquired the opacity and pearly lustre, often with the red, pink, grey or green tints distinctive of *common orthoclase*.

Sometimes the separation by chemical agencies of minute particles in the transparent mass has gone on in such a manner as to give rise to the scattering of light which results in "opalescence." We have thus produced the *opalescent orthoclase*, some forms of which are known as "moonstone."

If the change results in the formation and infilling by foreign deposits of negative crystals lying in their solution planes, then the result is an *avanturine* or *schiller orthoclase*, to which some of the so-called "sunstones" must be referred.

If the structures developed in the crystals by these agencies be of ultramicroscopical dimensions, we may have the beautiful interference phenomena produced, which are characteristic of *iridescent orthoclase*. The important researches of Stokes and Madan, and especially those recently undertaken by Lord Rayleigh, upon the artificially formed iridescent crystals of chlorate of potash, promise to throw much new light upon the obscure question of the theory of such a play of colours as exhibited by certain minerals.

The chemical changes which take place along certain definite planes within a crystal of orthoclase may result, not only in developing a particular lustre along these planes, but also in giving rise to a tendency to division along them (pseudo-cleavage), and we thus get the beautiful variety known as *Murchisonite*.

Lastly, the crystal after having undergone any or all of the changes above indicated, may, in consequence probably of changes of temperature, break up more or less regularly along certain planes ("contraction-rifts"); and, in the clefts thus produced, secondary deposits of albite or some other form of felspar may be deposited giving rise to the varieties known as *Perthite* and *Microperthite*.

Similar series of changes may be traced in the case of many—

perhaps of all—the rock-forming minerals, which have been subjected to deep-seated chemical action within the earth's crust.

*Secondly.*—The mineral (often greatly altered in its chemical constitution by one or other of the processes above described) may undergo complete transformation—either paramorphic or metachemic. Thus orthoclase, according to the nature of the solvents and the conditions under which they operate, may be converted wholly or in part into a zeolite, into muscovite or some hydrous mica, into epidote, into a kaolinite, or into some other type of mineral.

It may be interesting to illustrate in a tabular form the chief metamorphoses to which the species orthoclase appears to be subject, and the complete transformations of which it is ultimately susceptible:

A. *Forms dependent upon the conditions under which the crystals were originally produced.*

| | |
|---|---|
| Adularia. | Sanidine. |

B. *Forms resulting from physical or chemical changes, induced by statical or dynamical metamorphism.*

| | |
|---|---|
| Anomalous Orthoclase (Othose deformé). | Common Orthoclase. |
| Microcline. | Opalescent Orthoclase. |
| | Avanturine Orthoclase. |
| | Iridescent Orthoclase. |
| | Murchisonite. |
| | Perthite. |

C. *New minerals resulting from the further alteration of Orthoclase.*

| | |
|---|---|
| Zeolites. | Micas. |
| Epidotes, etc. | Kaolinites, etc. |

*Thirdly.*—Statical metamorphism, by giving rise to the development of new minerals in a rock or to the growth of old ones, may lead to a complete change in the structure of a rock. Holocrystalline rocks are those in which the whole of the materials have acquired the crystalline character without interruption, the time before their complete solidification having been sufficient for the prevention of any imperfectly crystallized residue being left. Such rocks may be regarded as being in the most stable condition. But with the hypocrystalline rocks the case is otherwise. We have a stable portion produced by the uninterrupted action, up to a certain point, of crystallization, and an unstable portion produced during the more sudden solidification of the residue. In such a rock, when subjected to the process of statical metamorphism, the stable crystals may grow at the expense of their unstable surroundings, and, as I have recently shown, many new and remarkable rock-structures may result from this process.[1]

It is very difficult to define any *limits* to the processes of statical metamorphism. The effects of such operations can be best studied in the case of igneous rocks—especially those belonging to a late period in the earth's history—that have been situated near volcanic centres and afterwards exposed to our study through denudation. In such cases the phenomena which have to be investigated are less liable

[1] Quart. Journ. Geol. Soc. vol. xlv. pp. 175-186 (1889).

to be complicated and obscured by the results of other processes of change, than in older rock-masses of similar origin. Around volcanic centres, too, the rate of the rise of the temperature with descent is probably more rapid, and the solvent agents are more abundant than elsewhere; and it is also more easy to trace the effects of these agents upon the definite minerals making up the plutonic rocks, than in other cases. But all rocks at great depths must be subjected to high temperatures, to enormous pressures, and to some solvent agents; and it may well be that at such depths a condition approaching to fusion or to solution may be reached, which permits of perfect recrystallization of the rock materials; such a state of things would seem to be advocated by Dr. A. C. Lawson and Dr. G. Dawson, as having probably occurred in the case of the rocks which cover so large an area in Canada.

I cannot perhaps better illustrate the complicated results of the joint action of statical and dynamical metamorphism than by referring, as briefly as possible, to the cycle of changes which can be shown to have occurred in the case of a particular rock.

The so-called Apatit-bringer of Oedegarden, near Bamle, in Norway, is a rock consisting essentially of hornblende and scapolite, which, as shown by the beautiful experiments of Fouqué and Michel Lévy, can, by fusion and slow cooling, be converted into an aggregate pyroxene and felspar. That the rock was originally a pyroxene-felspar-rock which has been metamorphosed into a hornblende-scapolite one, the observations of Sjögren and others sufficiently indicate, and we are now able to show the exact series of processes by which the transformation has been effected.[1]

In certain specimens the pyroxene (an enstatite) may be seen to have acquired, through a process of *statical* metamorphism, the peculiar characters of bronzite; and, by the same means, layers of cavities are developed along the twin-planes of the felspars, which cavities are filled with supersaturated solutions of sodic chloride.

Statical metamorphism having carried the change thus far, *dynamical* metamorphism has next come into play, and the bronzite has been converted into hornblende and the mixture of felspar and sodic chloride into scapolite; the former by a paramorphic, the latter by a metachemic transformation. At the same time the structure of the rock has been changed from a granitic to a granulitic one.

This particular case is one of more than ordinary interest from our being able to study all the stages in the complete cycle of change, from a pyroxene-felspar rock to a hornblende-scapolite one, and back again to the former. But there are many other instances in which careful study may enable us to follow many of the successive steps by which very similar changes have been gradually effected.

[1] Mineralogical Magazine, vol. viii. p. 186.

## III.—A Week's Geological Excursion to the Swiss Alps.

By Capt. Marshall Hall, F.G.S., F.C.S., etc.

THE following notes were drawn up by the writer some years since as a sketch for an excursion by members of the Geologists' Association to the Alps, and it may perhaps still prove acceptable to geologists who this year intend to visit Switzerland for the first time.

Leaving London any morning and proceeding onwards by the night-train from Paris, we may breakfast at Lausanne railway-station on the following morning.

Take steamer from Lausanne (Ouchy) for Villeneuve, where we have a good example of an anticlinal valley—that of la Tinière. Thence by rail to Vernayaz, where sleep. I need hardly summarize the geology round Lake Leman; in the train from Villeneuve remark the wave-crest form characteristic of the Jura seen from north, and the rock-fall at Roche; on the right the great one near Vouvry. The Triassic rocks are all interesting; and on the left after leaving Aigle are the fine marble quarries of St. Triphon. As you approach Bex you will observe the monticule called le Montet, which is principally a mass of gypsum. Bex with its salt mines would be well worth half a day's exploration.

Between that and St. Maurice we are in the Cretaceous formation. At the Baths of Lavey (left hand) we enter the Carboniferous region, consisting here of metamorphic schists. Remark any number of "roches moutonnées" and glacier-worn rocks. Of the picturesque nature of our route I say nothing—is it not recorded in many excellent guide-books?

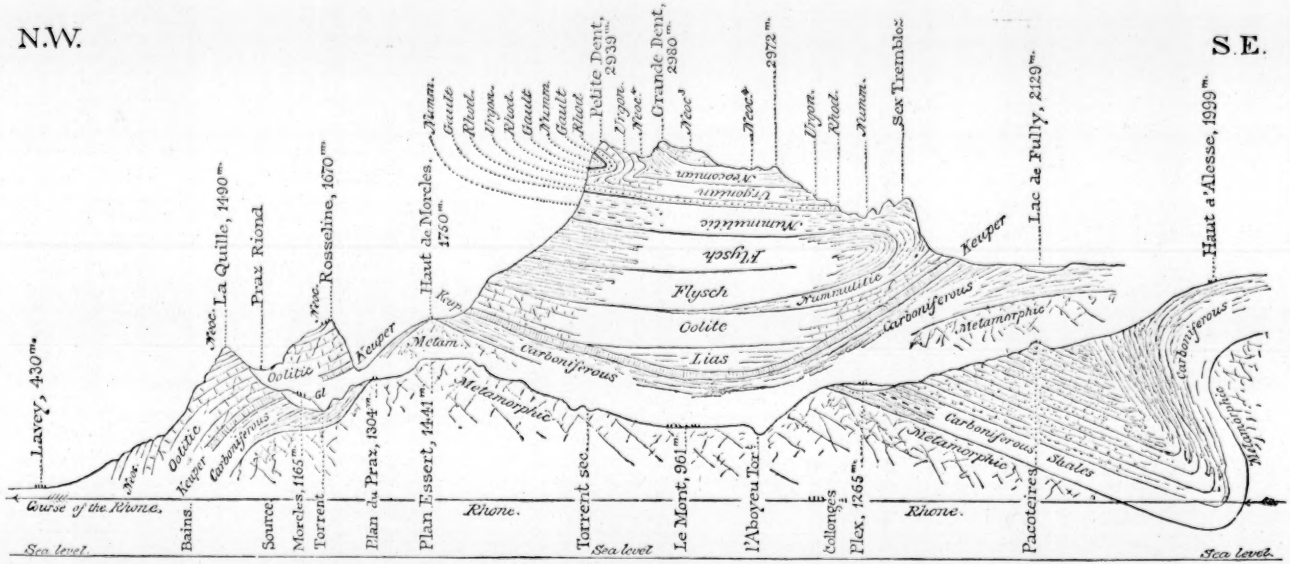
Next morning visit the Gorges du Trient, and thence the Pissevache, whence a rough zigzag leads over schists and by slate quarries to a point half-way up the carriage road to Salvan. This road winds up an interesting gorge, with a repetition on each side of slates at the bottom, Carboniferous grits, anthracitic and mica-schists and metamorphic schists, and grits. The heights above are gneiss.

Salvan is an hour and a quarter's fair walk from Vernayaz, up a good char road, but with a pitiless series of, I think, fifty-two zigzags, and, once fairly out of them, a gentle hill. Some ten minutes before reaching Salvan and five minutes off the road to the south-east are some very remarkable "marmites des Géants," *i.e.* the ancient pot-holes of glacial times, worn by water falling through "moulins." They show the pestle and mortar action, their centres rising in the form of cones.

On the opposite side of the valley of the Rhone the Dents de Morcles rising more than 10,000 feet have been growing more and more grand, and the replications of the strata, of which a sketch after that by Professor E. Renevier is given (see Pl. VIII. p. 251, opposite), are very specially remarkable, and, even at that distance, quite evident.

The geological map of the "Alpes Vaudoises," by the same geologist, marks "Poudingues de Valorsine" at Salvan.

One charming walk, scarcely known to the Cockney tourist, is a




*Geological Section of the Dents de Morcles, by Prof. E. Renevier.*

(Scale 1·50,000 for distances and altitudes.)

[Two sections combined and re-drawn from the originals by G. C. Crick, F.G.S.]

couple of hours up to La Creuse, whence is a splendid view of Mont Blanc. And I think the approach to the valley of Chamounix by this side of the valley far more interesting than that by the Tête Noire. The upper portions are gneiss. M. Renevier maps them as "schistes et grès metamorphiques," differing in this from the late Professor Studer, as the latter mentioned to me in several conversations.

The traveller should return to Vernayaz, or go on to Martigny, by the south-east side of the Trient, by the bridge of La Taillat and the hamlet of Guéroz. Thence he will take rail to Visp. The geological interest of the Valais increases, and its scenery is much under-appreciated. The Jurassic crags, peaks and precipices on the north side after reaching Saxon, are very grand and wild. The tendency of the Jurassic rocks to slope up like a heavy swell at sea, from the north, and, so to speak, break like the crests of waves in stormy weather on the south, is well exemplified. On the south side at the base of the mountains we have a different series, lowest are anthracitic schists, then a long strip of dolomite, extending to beyond Sierre, then banks of quartzite, and high up micaceous and other schists.

The flat valley, filled with old and recent alluvium, with the old Castles at Sion perched upon their craggy islands, the old moraines, especially about Sierre, would be excuse enough for the geologist to delay his journey at many points.

On arriving at Visp we start at right angles to the Rhone valley, ascending through the Schistes lustrés of Triassic age; then through some quartzite, and subsequently an occurrence of dolomite, then serpentine, which on the west side forms a not inconsiderable height. We then come upon mica and some chlorite schists, and, crossing a highly picturesque bridge, reach Stalden in less than two hours from Visp. Here we pass the night, well above the flies, queer odours, and generally doubtfully salubrious air of the Valais plain. Near Stalden are some notable stone-capped pillars and glacial detritus, resembling the well-known earth-columns of Botzen.

Leaving the valley of S. Niklaus to the right, next morning we begin to mount the actual Saas-Thal, to the south-east. Mark the blocks of gneiss perched on the hill-side, and study the water-worn gorge, with its wooden bridges and torrent roaring at great depths. We come to a level with the bed of the stream, and find therein a considerable variety of pebbles of schists, gneiss, serpentine, gabbros, etc. In four hours we reach Saas-im-Grund, and again come, in the valley sides, upon a bank of dolomite, between the older metamorphic schists and the gneiss of the central mountain mass. I have seen sections well showing the contact metamorphisms of this dolomite. I should be much obliged if any geologist having the time would kindly examine the relations of these occurrences of dolomite to the other rocks. Saas-im-Grund itself is upon the edge of schists and gneiss just mentioned, and it is worth while to spend the rest of the day in this field-work, and in walking forty minutes up the west side of the valley to Saas-Fée (where there is a good

hotel), for the sake of the grand views of the Fletschorn and other noble peaks to the east, and of the great Fée glacier and surrounding heights behind the village. In such case, and with a competent guide, it is not difficult to substitute a very interesting glacier walk for what I am about to describe as the next day's work, by making across the Fée glacier towards the Allalinhorn, and working one's way to Point 3150 mètres on the map, and so down to the Mattmark inn.

But if pressed for time, the traveller should walk or ride another three hours. In the bed of the torrents are beautiful specimens of the rocks of the country, in profusion. The rocks are schistose and gneissic on each side the valley. But on the west the Egginerhorn is of serpentine. Near Almagel is a gorge with waterfalls of great picturesqueness. As we advance, the forests become more and more scanty, and the scene grows wilder. The path, near a small roadside chapel, brings you almost within reach of the end of the Allalin glacier. I remember that in the year 1848 or 1849, the ice was far over the existing track, and the old path was above the present one in consequence. The plain has scanty herbage, moraine gravel and streams wandering where I remember the Mattmark-see (now an insignificant sheet), which could then boast the dignity of a small lake. Blocks of serpentine become more and more abundant, close to the Mattmark inn is one which I roughly guessed to weigh some 5000 tons or more, called the Blauen-Stein. This characteristic upper valley, surrounded with precipices and glaciers, with a frowning desolate aspect, will much strike the traveller. The rough inn, with its ingeniously varied dinners out of scanty resources, and warm welcome, is at a height of 7000 feet above the Mediterranean, and well placed for mountaineering and field-work. It is also only some couple of hours or so from the Col of Monte Moro, and as horses or mules can be taken all the way from the railroad at Visp to Thäliboden, that is, one hour from the top, one of the sublimest views in all Europe is attainable without difficulty or fatigue. I know nothing in the range of the Alps, after some forty years of devotion to them, which in its way is more imposing, grander or more instructive than the view which bursts upon the traveller, of the cirque of precipices and glaciers of the Monte Rosa chain—to say nothing of blue Italy. But a *very* early arrival is generally necessary to enjoy this in completeness.

Professor Bonney has written so much and well upon the Western Alps that I will not dwell upon their structure. But I will mention an exceedingly interesting day, or more, of work best done from the Mattmark inn. Although it is not actually in the considerable districts of serpentine which lie principally to the S.E. and S.W., the neighbouring heights are outliers of this mass. Also a rock of euphotide gabbro occurs within a morning's walk, which has I think supplied most of the erratic stones of this rock which occur on the north side of Lake Leman, and at the junction of the Rhone and Arve, below the town of Geneva, whilst, as regards the gabbros found on the south side of Lake Leman, as, for instance, about Evian,

I take it the mountains at the head of the Val d'Herens were their source, the widening Rhone glacier of old having spread out as it advanced. I come to these conclusions from microscopical examination of rocks, erratic and not in situ.[1]

If we leave the inn betimes on a fine morning, we shall find the torrent at its lowest, and, crossing it by a wooden bridge of the roughest construction, we traverse a meadow, and at once begin to ascend a steepish zigzag up a ridge partly of rock, partly of old moraine. Chalets some 1000 feet above the valley would give shelter at a pinch, and milk when inhabited. An hour more up the Schwartzberg brings us to the Aeusser Thurm, which, as also the Inner Thurm a little further on, overhangs the Schwartzenberg Glacier on the S.E. side, and on the N.W. joins the Névé of the Allalin Glacier. We cross the latter, but, as it is in this part treacherous (owing to concealed crevasses), though not steep, we must either be three in number, roped, and experienced, or have a guide (and always a rope). In half an hour we shall reach the foot of a rock marked in the Swiss map 3150 mètres (10,333 feet), and this is our mountain of euphotide. A climb without difficulty, but requiring caution, will in half an hour place us on its summit, and amongst its innumerable detached blocks we shall have found a 'quantum sufficit' of gabbros. Chloritic schists and serpentines characterize its surroundings, and the mass itself is far from being altogether euphotide. Now a geologist having started early and exploring the adjacent ridge, which leads up to the Allalinhorn, would fulfil the errand which took me there, but which I was unable to carry out from the rocks being concealed by an unusual quantity of snow in 1880.

I was especially desirous to ascertain the exact relations of the presumably intrusive euphotide with the serpentine and other rocks surrounding it, and also to observe the effects of its contact with its neighbours. I failed ignominiously, though in other respects my scramble was delightful and its results satisfactory. There is another point—in the large Swiss map, a rock in the middle of the Allalin Glacier is marked 3368 mètres. In that snowy year I think it must have been covered, or the glacier itself have previously increased in volume, for I could see nothing of it—the whole seemed névé. Now I much wish to know its nature, and should be grateful for specimens of it, and of the ridges leading up to the Allalinhorn and from the Inner Thurm to the Strahlhorn.

Let the geologist be cautious as to falling stones, and bear in mind that serpentine, though a good solid rock, is perfectly awful to slip upon.

In this skeleton of a tour the only occasions upon which a guide is at all necessary—though an intelligent mountaineer is always a useful and agreeable companion—is the scramble just described, and its alternative route from Fée. For these, and all walks in big mountains, a guide is a matter of prudence. I have now climbed for forty years, and still hold this mountaineering dogma.

[1] Vide Mineralogical Magazine, June, 1883.

I have now briefly indicated a few of the innumerable matters of interest most prominent during a course up part of the great Rhone valley and across the various schists and other formations to the centre of the Western Alpine mass. I could go on, could keep my unfortunate geologist hard at work, week after week, over this hastily surveyed ground. But I should be writing a book!

With regard to fossil remains. Switzerland is so bad a hunting ground that, unless a specialist wishing for details of a particular formation, the palæontologist will grow discontented. But for the history of mountain formation, and—pace Heim—metamorphism, not a spot in this wonderful country but tells its story of one or other.

And now I basely desert my traveller! If a scrambler, I advise him either to take the Weiss-Thor pass and sleep at the Riffel Hotel, or descend by the new Weiss-Thor pass which I first found in 1849, to Macugnaga. Whence, should the proposed excursion of the Geologists' Association to Naples take place, he might join those who may have crossed the Simplon at Vogogna. If no mountaineer, he must even ride or walk down to Stalden by the way he came. Somehow or other he will I trust get home after much enjoyment.

The geologist will find excellent official geological maps with memoirs and a large scale ordinary map (Siegfried) $\frac{1}{50000}$ at Mon. Rouge's, a leading bookseller in Lausanne. But it would avoid possible delay to bespeak them.

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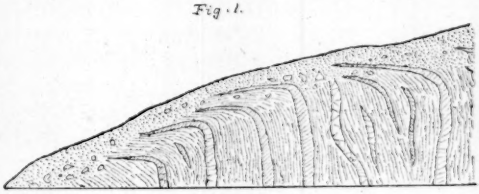
## IV.—On the Creeping of the Soilcap through the Action of Frost.

By Charles Davison, M.A.,

Mathematical Master at King Edward's High School, Birmingham.

1. The object of this paper is to show how the soilcap, or its upper portion, may creep down an inclined surface through the action of frost. The subject has also been discussed by Mr. W. C. Kerr in a valuable memoir, "On the action of frost in the arrangement of superficial earthy material,"[1] published in May, 1881. I

*Fig. 1.*



reproduce here one of the figures given by Mr. Kerr, as I cannot better describe the nature of the phenomenon which it is the aim of this paper to consider.

"During the Centennial Exhibition [at Philadelphia], Market Street was extended westward . . . . . and a hill of some twenty

[1] American Journal of Science, 3rd ser. vol. xxi. pp. 345-358.

feet was brought to grade in the process. . . . . The rock is gneiss and mica-schist with hornblendic and chloritic strata, inclined at a high angle, and decomposed, for the most part, the entire depth of the cut [not more than three to four feet in the portion sketched], presenting a banded section of variously-coloured earths. The most striking and novel peculiarity of this section is shown in the sketch (Fig. 1, *ante*, p. 255), viz. the gradual drawing out,—attenuation of these coloured bands, as the parts of them in succession were moved down the slope" (p. 353).

After remarking on the great depth of frozen soil in Canada and Labrador during their present winters, and on the still greater depth to which it must have penetrated during the Glacial period, Mr. Kerr says: "The alternate freezing and thawing of the saturated mass of decayed rocks . . . . would of necessity produce just the movement and settling which are described above. That is, this freezing and thawing would give rise to precisely the same movements of the mass, and of the particles *inter se*, as are seen to occur in the true glacier, *differing only in amount*. In other words, these masses were *earth glaciers*, and these deposits may be denominated *frost drift*, as distinguished from proper glacial drift" (p. 352). The majority of these deposits Mr. Kerr refers to glacial age; but, considering the small thickness of that illustrated in Fig. 1, he remarks that "the probability is strong that it is of recent (*present*) origin, the existing climate of Philadelphia being equal to the production of such effects" (p. 353).

It is not clear from this description how Mr. Kerr supposes the freezing and thawing to have acted in producing this movement of the soilcap. My first impression after reading his paper was that the water in freezing would, by its expansion, force the mass of loose earth bodily down the slope. This may be the case in certain parts of the mass, but that the explanation cannot be generally true will, I think, be evident after I have described the way in which I believe the movement must as a rule take place, together with some of the experiments made to test the theory.

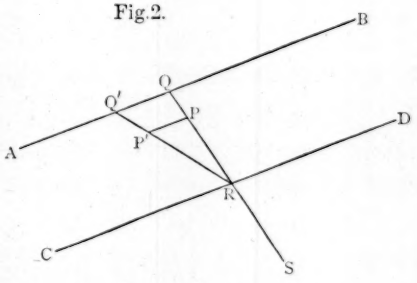
2. Imagine a layer of damp earth resting on an inclined surface, and exposed to the action of frost. The water in the interstitial pores will be frozen to a depth depending on the intensity and duration of the frost. If the particles of soil be not closely packed, the water will, in freezing, expand into the spaces between them, and the relative position of the particles may not be altered in consequence. But this cannot often be the case, for freshly-turned earth is soon rendered close and compact by a few showers of rain. The distances between the separate particles will thus as a rule be increased when the water between them is frozen. Now, the soil being compact and, except near the edges of the mass, continuous, the only direction in which expansion can readily take place is outwards and perpendicular to the surface. Every particle of soil in the frozen layer will therefore be displaced from its original position along the line of the normal (or perpendicular) to the surface of the soil; and, if the water be equally diffused throughout, the amount of the displacement will be proportional to the

distance of the particle from the surface to which freezing extends. The more intense and lasting the frost, the thicker will be the frozen layer, and the greater the displacement of the surface particles.

On the recurrence of warmer weather, the interstitial ice will be melted, and in melting will contract, and the particles will return, not, as they came, along the normal to the surface, but in a direction nearly vertically downwards owing to their weight; not quite vertically, however, because the adherence of each particle to its neighbours, by reason of the water between them, tends to bring it back towards its old position. The particles will thus after every frost and thaw occupy a lower position down the slope than they did before; and the whole outer layer of the soilcap will in this way creep slightly downwards, the creeping being greatest at the surface, and diminishing downwards to zero at the greatest depth to which freezing extended.

3. If all the particles descend vertically during the thaw, or at any rate in the same direction, it may be shown that a series of particles lying in a straight line will, after a single frost and thaw, continue to lie in a straight line, inclined, however, at a different

Fig. 2.




angle to the horizon. Let A B (Fig. 2) represent the surface of the soil, C D the surface to which freezing extends. Let P be any particle of soil on the straight line Q R. Its normal displacement, and therefore also its creep, P P′, will be proportional to the distance of P from C D, and therefore to P R. Hence, the series of particles originally lying along the straight line Q R, will, after the frost and thaw, lie along the straight line Q′R; and the effect of the creeping will be to bend the line Q R S into the form Q′R S.

4. But, since during any winter or series of winters, there must be numerous frosts of different degrees of intensity and duration, and therefore penetrating to different depths, and since the surface layers of soil are affected by every frost, however slight, and in any one frost are more displaced than those below them, it follows that after any given time (including many changes of temperature across the freezing-point), particles lying originally on a straight line will in the end lie on a curved line with its concavity facing downwards.

If the different frosts be of different degrees of intensity and duration, the resulting line will be curved throughout its whole length, down to the lowest depth to which freezing has extended. But if, as in colder countries than ours, the frost last through nearly the whole winter, and in different winters do not vary greatly in its depth of penetration, then the resulting line will exhibit a more or less sharp bend at the average depth to which the frosts are felt, and above the bend they will be fairly straight. Mr. Kerr's section (Fig. 1) seems to me to agree remarkably with this latter deduction; and it will be observed also that the bends are all at nearly the same depth, which ought to be the case when the surface is not very uneven.

5. The experimental evidence that I have been able to obtain, though less varied and complete than it might have been made in a colder country, is decidedly confirmatory of the above theory. The experiments were made in boxes inclined to the horizon, and in this respect the conditions were not quite natural, for the sides and bottom of the boxes, as well as the surface of the soil, were exposed to the cold. But the movements of the surface-particles near the middle of the boxes would not be affected by this. The method adopted, moreover, possesses several advantages, not the least being that the effects are more marked than they would be naturally, owing to the greater depth of frozen soil.

Two boxes, differing in form, were filled with damp, fairly compact, soil. The first (A) is, internally, $2\frac{1}{16}$ inches wide, $2\frac{7}{8}$ inches deep, and, at the surface, 13 inches long; the lower end is horizontal, the upper vertical; and the inclination of the bottom of the box and the surface of the soil is 32°. A straight bar of wood is firmly screwed to upright supports at either end of the box, so that its lower edge is parallel to the surface of the soil and at a distance of $1\frac{1}{4}$ inches from it. The other box (B), rectangular in form, is, internally, $15\frac{1}{4}$ inches long, six inches wide, and $6\frac{3}{4}$ inches deep; and is inclined at an angle of 27°. A straight bar of wood is also fixed to the box, with its lower edge parallel to the surface of the soil and one inch from it. Fine pencil-lines are ruled on both bars in several places, perpendicular and parallel to the lower edges; and serve as reference-lines for the measurement of the displacements. I will now give an example of the experiments made with each box.

6. *Experiment* 1.—(Box A). The index used to register the motion of the soil consists of a slab of sheet-lead, $\frac{7}{8}$ inch square, on two opposite sides of which are arms, one inch long and $\frac{1}{4}$ inch wide. These are bent towards the centre of the slab, and, when they meet, bent again so as to be perpendicular to the slab. Part of a stout needle, $1\frac{5}{16}$ inches long, is bound tightly with strong silk between the projecting arms. The whole index weighs a little over three-fifths of an ounce.

The index was placed so that the surface of the soil was level with the upper surface of the slab, and the soil was pressed closely all round it, so that there was no gap between the soil and the edges

of the slab. It was then left some days, and afterwards placed outside on the window-sill of an unused room, on the evening of January 3, 1889; and the distances of the needle-point from the lower edge of the bar and one of the lines perpendicular to it were carefully measured with the aid of a pair of bow-compasses.[1]

The minimum temperature during the following night was 27° F. and the soil was evidently frozen through by the next morning. The needle-point had risen $1\frac{1}{2}$ mm. in a line almost exactly perpendicular to the surface of the soil; and it remained in this position until the night of Jan. 7–8, when a thaw set in, by which the ice in the soil was entirely melted in about twelve hours. During this interval the position of the index was recorded several times; and the displacements measured, though very small, showed that the needle-point descended in practically a straight line, so as to end at the same distance from the lower edge of the bar as at starting, but $\frac{3}{8}$ mm. further down the slope. The direction of descent was therefore not quite vertical, but approximately bisected the angle between the vertical and the normal to the surface of the soil. Also, the normal rise of the surface-particles was about $\frac{1}{4\frac{1}{8}}$ of the depth of the frozen soil, and their creep downwards about $\frac{1}{10\frac{1}{2}}$ of the same depth.

At first sight, it seems possible that this creep may have been only apparent, and due to the weight of the index, which is of course much greater than that of an equal volume of soil. But I noticed carefully that, after the thaw, there was no gap between the lead slab and the surrounding soil; and this could hardly have been the case if the movement of the surface-particles had been very different from that of the index. The following experiment, however, appears to me to remove this objection, if it be one.

7. *Experiment* 2.—(Box B). An index, similar to that used in the preceding experiment, was placed on the surface of the soil, in order to measure its normal rise. Two fine grains, half a millimetre in diameter, of very hard red drawing-chalk were also inserted into very small holes made in the soil to receive them. One of these was exactly in a line with the edge of a long pin (a lady's hat-pin) fixed at right angles to the bar, and penetrating the soil. The other was just underneath the point of a similar pin constrained to slide in a straight groove perpendicular to the lower edge of the bar. Before the soil was frozen, the point of the pin was drawn up a short distance, and brought close down to the soil at the end of the frost and again after the thaw.

The box was put outside on February 9th, and by the 12th inst. the soil was frozen through. The needle point of the index had risen normally $3\frac{3}{8}$ mm., and the two red grains had also risen normally, and probably the same distance. Later on Feb. 12th the thaw began, and the interstitial ice was quite melted the next day. After the thaw, the needle-point of the index was found at $\frac{1}{4}$ mm. above its original distance from the lower edge of the bar, and 1 mm.

[1] The measurements thus made are probably correct to one-eighth of a millimetre.

further down the slope. One of the red grains had crept $\frac{3}{4}$ mm., and the other 1 mm. down the slope. The soil particles must therefore have descended along a line inclined at an angle of about 17° to the normal to the surface of the soil. The normal rise of the surface particles was about $\frac{1}{4\,0}$ of the depth of the frozen soil, and their creep about $\frac{1}{1\,6\,5}$ of the same depth.

8. Now, if the creeping of the soilcap through the action of frost were due to the expansive force of the freezing water urging the mass down the slope, it is clear that the downward movement should take place during the frost and not during the thaw; but the experiments just described show that this is not the case, unless it be along the edges of the mass of frozen earth. Again, if this explanation were the correct one, the whole frozen layer at any point would be displaced equally throughout its depth, and there would be a rupture of continuity between the frozen and unfrozen parts of the soilcap. Hence, any line inclined to the surface would, after a succession of frosts of different degrees of intensity and duration, exhibit a series of breaks forming miniature faults parallel to the surface of the ground. And, if the principal frosts of every season penetrated to approximately the same depth, then, at that depth, the fault-displacement would be greatest. It need hardly be said that this inference is not supported by Mr. Kerr's section given in Fig. 1. Both reasoning and experiment are in favour of the view that creeping takes place by a normal rise during the frost and a more or less vertical descent during the thaw.

9. It would be interesting to determine, if we could, the length of time required for the production of the effects illustrated in Fig. 1, but the data are too imperfect to enable us to form more than a very rough estimate. Judging from the figure, the creep near the surface is on an average about three times the depth of the bends. If the amount of creeping of the surface particles be the mean of the values given by the experiments recorded above, namely, $\frac{1}{1\,7\,7}$ of the depth of frozen soil, and if there be only one important frost and thaw every winter, then the time required may have been about 531 years. But the assumptions involved in making this estimate are too great to allow us to place any reliance whatever upon its accuracy. It is just possible, however, that it may indicate the order of magnitude of the real interval of time.

10. Lastly, the conditions which are most effective in producing the creeping here considered are neither those of a temperate climate, in which there may be many alternations of frost and thaw in one winter, nor those of an arctic or glacial climate; though probably nearer those of the latter than of the former. Other conditions being the same, the amount of creeping (measured by the product of the volume of soil moved into the average displacement down the slope) varies as the square of the depth to which the frost penetrates. Thus, if in one place, the soil be frozen to a depth of one foot, and, in another, to a depth of three feet, the creeping of the surface-particles in the latter will be three times as great as in the former, and the volume of soil affected also three times as great: hence the

amount of creeping in the second place will be nine times that in the first. And it seems hardly possible that there should in any country be nine separate frosts in one winter each penetrating to the depth of one foot.

On the other hand, in arctic countries, the soil is permanently frozen at a certain depth, and the amount of creeping then depends on the depth to which the soil is thawed during a comparatively short summer. We may conclude, therefore, that the amount of creeping will be greatest in that place in which the soil frozen in winter, and also thawed in the following summer, attains its maximum depth.

## V.—Notes on the Wicklow Greenstones.

By Frederick H. Hatch, Ph.D., F.G.S.

(Communicated by permission of the Director-General of the Geological Survey.)

THE Wicklow greenstones occur in sheets and dykes intrusive in the Lower Silurian slates (the equivalent of the Bala beds of Wales) that lie to the east of the main chain of the Leinster granite. Like the Welsh greenstones, they are associated with acid lavas (felsites and keratophyres) and felspathic tuffs, although of slightly later origin than these.

In a petrographical appendix to the memoir on Sheets 138 and 139 of the Map of the Irish Geological Survey, I have given some notes on the microscopical characters of the more important types. These notes were based on sections made from rocks collected in June of last year. In November and December I had another opportunity of visiting the ground, in company with my colleagues Messrs. Cruise and Clark; and this visit threw fresh light on certain points not cleared up on the first occasion, especially with regard to the mechanically deformed greenstones, and also furnished me with an additional supply of material for microscopical investigation. As the publication of the memoir could not be delayed until this fresh material had been thoroughly worked out, perhaps I may be permitted to communicate in this place my results, coupled with a brief abstract of what has already appeared in the memoir.

The Wicklow greenstones have this advantage over those of many other areas, that they present a greater variety in structure and composition. Offering this attraction it is somewhat surprising that they have received such scant attention at the hands of the microscopist. The literature on the subject is indeed meagre, and may be disposed of in a very few lines.[1] Prof. von. Lasaulx,[2] during a short visit to Ireland in 1876, collected some specimens which he described as diabase, diorite, and mica-diorite. The Allport collection in the British Museum contains a few sections of Wicklow greenstones. These have been described by Mr. Teall in his British Petrography.[3]

[1] Professor Haughton gave a brief description, with two analyses, of the Westaston greenstone as early as 1859 (Trans. Roy. Irish Acad. vol. xxiii. p. 619); but I am referring to microscopical work.

[2] "Petrographische Skizzen aus Irland," Tschermak's Min. u. Pet. Mitth. vol. i. 1878, p. 441.

[3] 1888, pp. 249 and 266.

In the notes appended to the memoir referred to above, the greenstones there described are arranged in the following categories:—*a*. Quartz-mica-diorite; *b*. Quartz-diorite and diorite; *c*. Augite-diorite; *d*. Dolerite (diabase); *e*. Epidiorite (passing into hornblende-schist); and *f*. Serpentine.

(*a*) *Quartz-mica-diorite* (the Tonalite of vom Rath).—A fine example of this rock occurs as an irregular boss, extending from Carrigmore to Westaston, 4 miles E. of Rathdrum (Sheet 130). The central portion of the mass is traversed by the road going from Rathdrum to Kilboy Bridge. The rock is remarkable for its granitoid appearance, the grain being moderately coarse and the colour light. Some parts of the mass are spangled over with lustrous six-sided plates of dark mica; while in others the mica is replaced by chlorite. At Carrigmore the mica occurs in thin bronze-coloured films, covering irregular patches of the rock's surface. Under the microscope these patches appear as ophitic plates of a bright reddish brown colour.

The component minerals of the rock are quartz, felspar (mostly plagioclase, but with a small quantity of orthoclase), biotite, a pale green hornblende, a few grains of colourless augite (malacolite), chlorite, and apatite.

The quartz is abundant. It was evidently the last mineral to separate, since it fills the interspaces between the idiomorphic crystals of the earlier-formed minerals. Apatite is also present in considerable quantity; and its six-sided acicular microlites are found penetrating all the remaining minerals. The chlorite has resulted from the alteration of the mica, the plates of which are sometimes surrounded by a border of chlorite, sometimes altered almost completely into that mineral.

(*b*) *Quartz-diorite* and *diorite*.—An excellent example of quartz-diorite occurs at Bologh Lower, three miles E. of Rathdrum. The rock is a medium-grained granitic aggregate mainly of felspar and quartz, but with some green hornblende and chlorite. Both monoclinic and triclinic felspar are present, the former being fresher than the latter.

The interspaces between the felspar-crystals are filled by clear quartz. Green hornblende occurs, sometimes in idiomorphic crystals that are evidently original, sometimes in granules and needles, imbedded in patches of chlorite, and then perhaps of secondary origin.

In structure and composition the rock much resembles a hornblende-granitite; but mode of occurrence and association show that it belongs to the greenstone rather than the granite family.

Similar rocks, but with less abundant quartz, occur near Cummer Place, six miles E. of Shillelagh. These are true diorites.

In all of them the effects of dynamic metamorphism are occasionally met with, in the shape of finely-granulated patches — the so-called "quartz-felspar-mosaic" — resulting from a molecular rearrangement of the original felspar.

(*c*.) *Augite-diorite*.—This type is very common among the Wicklow greenstones. It consists essentially of plagioclase felspar

and a pale variety of augite (salite or malacolite). Interstitial quartz is sometimes present; and there is a complete absence of ophitic structure, the augite occurring in isolated and often well-contoured crystals: both, points of distinction from dolerite. The felspar occurs in crystals giving lath-shaped sections and exhibiting the twin-striation characteristic of plagioclase. It is sometimes enveloped by patches of clear quartz, somewhat in the same way that felspar-lathes are enveloped by augite in the dolerites.

Rocks of this character occur abundantly in the neighbourhood of Kilpatrick House, N. of Arklow. The exact localities are given in the memoir.

(*d.*) *Dolerite* (*diabase* of the Germans).—The rocks considered under this head are composed essentially of plagioclase and augite, with a well-marked ophitic structure. The Wicklow type is entirely free from olivine, and passes by the addition of quartz, accompanied by a change in the nature and structure of the augite, into augite-diorite, to which it is naturally closely allied.

The best representatives of this group occur in the neighbourhood of Arklow Head, where they are quarried for road-metal by Mr. Parnell.

The dolerites pass readily into epidiorite; and even when the rock, examined under the microscope, appears, at first sight, to be quite unaltered, a narrow zone of secondary hornblende will, on nearer examination, sometimes be found fringing the augite-patches. But the more detailed discussion of these changes is reserved for the next section.

(*e.*) *Epidiorite.*—The rocks embraced under this head are dolerites that have undergone alteration under the influence of dynamic metamorphism. Originally they were plagioclase-augite rocks; but, as a result of the metamorphism, the augite has been more or less completely converted to hornblende. This mineral occurs in ragged patches, which in most cases still present the ophitic structure of the augite which it has replaced. Other new-formed minerals are chlorite, epidote, leucoxene, sphene and calcite. The leucoxene often presents elongated streaky forms, suggesting linear extension. Further evidence of mechanical metamorphism is to be found in the cataclastic structure frequently presented by the felspar; in such cases the mineral loses its homogeneity and appears as a minutely granular mass, giving aggregate-polarization (“*felspar-quartz-mosaic*”). In places where the movements have been great, the rock assumes a highly schistose character, and in such places a considerable proportion of the hornblende is often replaced by chlorite.

All degrees in the mechanical metamorphism of a greenstone can be well studied in the Aughrim Valley, between Woodenbridge and Coatsbridge (Sheet 139). The altered rocks occur here in sheets, intercalated between the Lower Silurian beds, and are correctly represented on the Survey Map as a series of lenticular bands, striking N.E. and S.W. At the time when this ground was surveyed, however, the effects of dynamic metamorphism had not yet been recognized, consequently the schistose character of these

rocks caused them not unnaturally to be regarded and mapped as tuffs ("greenstone-ash").[1] In the smaller sheets the foliation is very striking, the whole of the rock being converted into schist; the thicker bands, however, are foliated only at the margin, *i.e.* near the junction with the slates.

About one mile and a half west of Woodenbridge one of these larger bands has been well opened out by a quarry; and the successive stages of alteration admit there of easy study. The central portion of the sheet is not foliated. It is composed of a granular aggregate mainly of plagioclase, and hornblende, secondary after augite. The hornblende is the ordinary green variety (actinolite), and shows pleochroism in bluish-green and yellowish-green tints. It occurs in patches, which, though often compact towards the centre, are usually bordered by a fibrous fringe. These patches are penetrated by needles and prisms of turbid felspar, thus indicating the ophitic structure of the original augite. In rare instances a nucleus of augite still remains, thus removing all doubt as to the secondary nature of the hornblende. The presence of isolated patches of chlorite shows that hornblende does not represent the final stage of alteration; for the chlorite appears to be derived from the hornblende, and thus to bear only a tertiary relation to the augite. Other secondary minerals are epidote, in granular aggregates, leucoxene, in white turbid grains after ilmenite, and calcite. The epidote is derived mainly from the felspar, the original crystals of which are replaced by a mosaic of minute granules of secondary felspar, doubtless a variety less rich in lime—such as albite, or oligoclase.

A fibrous asbestos is developed between the slickensided joint-faces.

Near the junction with the slates the rock assumes a marked foliated character. In thin sections made from this portion of the rock the hornblende appears in narrow fibrous bands, alternating with layers of a cryptocrystalline aggregate of felspar together with grains of original felspar. Secondary quartz is associated with the new-formed felspar, and chlorite with the hornblende. The chlorite increases in proportion to the amount of alteration, until finally we get a highly fissile lustrous schist, in which chlorite greatly predominates.[2]

Some specimens of these highly altered schistose rocks, for instance one from a band two miles west of Woodenbridge, contain abundant grains of sphene, and it seems probable that this mineral has been produced by a molecular reconstruction of the turbid leucoxene derived from ilmenite.

Some of the greenstone-bands that cross the Aughrim Valley are

[1] According to Mr. W. M. Hutchings (this MAGAZINE for February, 1889, p. 53) the same error has been committed in Cornwall, De la Beche having held certain "schistose trappean rocks," which Mr. Hutchings has proved to be mechanically metamorphosed greenstones," for altered ash.

[2] Similar alterations are described by Mr. Hutchings in the Tintagel rock (*loc. cit.*), and by Mr. Teall in a greenstone occurring at Garth near Portmadoc (Brit. Petrog. p. 216).

prolonged in a south-westerly direction towards Croghan Kinshelagh. A specimen, collected from a spot one mile north of the summit of this mountain, proved, on examination with the microscope, to be a typical epidiorite. The rock forming the summit itself has undergone more alteration. It has a marked foliated character, and consists mainly of chlorite and "felspar-mosaic." Sphene is also present in abundant grains.

Specimens of epidiorite were also collected about a mile N. of Wicklow, on the S.W. side of Croghan Kinshelagh, and from a small patch of greenstone two miles east of Kilcavan House, to the east of Shillelagh (Sheet 138).

(*f.*)—In only one case was the occurrence of a serpentinous greenstone noted. My attention was drawn to this rock by Mr. Kinahan. A small patch of it occurs about half a mile west of the patch of epidiorite referred to above, two miles east of Kilcavan House, near Shillelagh. Unfortunately I was prevented by lack of time from visiting the locality myself, and the specimen examined was collected by Mr. Clark. The rock is of a variable green colour, and has the characteristically soapy "feel" of a serpentinous rock. A microscopic section discloses the serpentine in colourless layers, associated with grains of opaque iron-ore and a finely granular substance resembling calcite or dolomite. The powdered rock, treated with hydrochloric acid, effervesces only on warming; it contains, therefore, as we should expect, the magnesian carbonate.

The texture of the serpentine is well brought out between crossed nicols. It has rather the "netted" or "bladed" structure of serpentine derived from augite than the "lattice"-structure peculiar to that mineral when produced by the alteration of hornblende.

Whatever may be the nature of the alteration, there can be little doubt that we have here the final product of the alteration of a greenstone (dolerite). As we have seen above, the usual course of the metamorphism of the Wicklow dolerites is, first, the formation of a hornblendic rock (epidiorite, hornblende-schist) and, finally, a chlorite-schist; but the case in point indicates that there are exceptions to this rule.

28, Jermyn Street, S.W.

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## VI.—Devonian Greenstones and Chlorite Schists of South Devon.

By Miss C. A. Raisin, B.Sc.

In a paper published in the Devonshire Transactions for 1888 (p. 215), Mr. Somervail suggests the identity of the chlorite schists of South Devon with certain rocks to the northward. As this hypothesis (could it be established) would have a most important bearing on subjects of controversy, I took the opportunity in a few days this winter, to visit and collect from these localities, including the dyke nearest to Torcross. I was not rewarded by finding any striking similarity to the metamorphic rocks of the south. In that

series, the chlorite schists consist of clear and definite crystalline grains, among which I find felspar to be rare and have not yet certainly identified augite—while these northern greenstones are full of broken crystals of both minerals, together with viridite, dust resulting from the crushing, and a small amount of minute secondary hornblende and sericite (?), chlorite being generally rare, and often absent. The one rock is a true schist, the other nothing more than a schalstein. If Mr. Somervail ascribes the marked difference in character to more intense pressure, a very obvious difficulty would have to be met. As pointed out by Prof. Bonney, the chlorite schist exhibits at places not only a well-defined mineral banding, but also a cleavage cutting transversely across it, which appears to be in close relation with the general cleavage of Devonshire.[1] If, therefore, pressure metamorphism be invoked to account for the origin of the chlorite schist and its banding, the force must be relegated to an earlier period, and thus the rocks affected by it, even if originally igneous, cannot be of Devonian age.

Of themselves, however, these schistose rocks afford interesting study, as in the case of other west-country greenstones.[2] One type[3] (from the coast near Redlap, and also from a quarry for road metal N.W. of Stoke Fleming), is clearly an ophitic dolerite,[4] but exhibits changes which have resulted from the crushing of the rock. Much of the augite is still very fresh and clear, but it seems to have been brittle, and to have broken along cleavage planes, forming fragments with sharp straight boundaries. Often there is a border of a hornblendic mineral, partly an alteration product,[5] although some is not unlike the serrate fringe of 'secondary enlargement' described by Van Hise,[6] having cleavage planes continuous with those of the original crystal. A fibrous hornblende, which is probably asbestiform, also seems to have formed at places, where a fragment of augite has been drawn out in the shearing of the rock. Elsewhere, as Professor Bonney suggested to me, strands of a very pale viridite seem to be connected with remnants of augite crystals,[7] and, in some cases, the viridite encloses small pieces, fragmental in outline, now converted into fibrous actinolite, which very probably have resulted from the crushing of a crystal of the pyroxene. Professor Bonney sug-

[1] Q.J.G.S. 1884, vol. xl. p. 8, fig. 4, p. 22.

[2] Q.J.G.S. 1876, vol. xxxii. p. 407, S. Allport. Q.J.G.S. 1876, vol. xxxii. p. 155, and 1878, vol. xxxiv. p. 471, J. A. Phillips. Q.J.G.S. 1880, vol. xxxvi. p. 285, and 1886, vol. xlii. p. 392, F. Rutley. Brit. Petrogr. J. J. H. Teall, p. 228.

[3] Somewhat like the Carlion rock (No. 7) of Mr. Rutley, Q.J.G.S. 1886, p. 397. The augite resembles that of fig. 2, p. 398.

[4] *Cf.* Mr. Allport, Q.J.G.S. 1876, p. 419.

[5] As, for example, in the Lizard gabbro and basalt. Q.J.G.S. 1877, vol. xxxiii. pp. 904, 907, Prof. Bonney, "On the Serpentine and Associated Rocks of the Lizard." See also Q.J.G.S. 1885, vol. xli. p. 520, "On the so-called Diorite of Little Knott," and Q.J.G.S. 1883, vol. xxxix. p. 256, "On Hornblende Picrite from Anglesey," Prof. Bonney. Also Q.J.G.S. 1878, p. 493, J. A. Phillips. "Perimorphic" hornblende of Mr. Harker, Q.J.G.S. 1888, vol. xliv. p. 452.

[6] Amer. Journ. Science, 1887, vol. xxxiii. p. 388, fig. 3; also U. S. Geol. Survey, 5th Rep. 1883-4.

[7] *Cf.* Brit. Petrogr. J. J. H. Teall, pp. 216, 230.

gested that this difference, in the results of the transformed augite, might be due to an admixture of the constituents of felspar obtained in the crushing, either from ophitic plates or from the surrounding mass. The felspar in the slide has been completely decomposed, and the ophitic plates can be identified mainly by their sharp outlines, preserved within the surrounding augite. Rarely a granular crystalline aggregation seems to mark a former felspar now replaced. Thus this rock is actually in a condition of transformation, and seems to point out what may result from the crushing of an ophitic dolerite. Planes of schistosity have been formed, characterized by streaks of viridite, probably derived mainly from the pyroxenic constituent, and the larger films may mark the loci of what were once augite crystals. Secondary hornblende has formed by recrystallization, along the exterior of original crystals, or from the shearing, possibly of an unmixed augite. A dusty and granular ground-mass, partly kaolinitic, has resulted from the powdering up of other constituents, including the greater part of the felspar.

A slide from rock of a second type is crowded with plagioclase felspars, exceptionally well preserved, although they have been much broken and snapped by strains acting on the mass. Crystals of iron oxide are abundant, some being clearly ilmenite. The structure of this rock is difficult to interpret, but the felspars seem to have occurred as porphyritic crystals, and not to be pyroclastic. Professor Bonney has suggested to me, that the ground-mass might be that of a crushed glassy rock, possibly andesitic, and that the greenish mineral, which is abundant in it, might perhaps be best classed as a variety of palagonite. Mr. Rutley describes and figures certain rocks from Cant Hill, near St. Minver, which he believes have been derived from what was once a rather basic glass, and this slide from Redlap seems to have a ground-mass something like that of fig. 1—with broken felspar similar to that of fig. 3.[1] I have not, however, recognized in these Devonshire specimens the vesicular structure, which the other rocks exhibited.

In a third type of rock, the ground-mass seems to have been felspathic, sometimes crowded with well-defined felspars, which are now altered to a filmy mineral (? sericite). Porphyritic crystals can be traced, which have undergone an aggregate replacement. Other groups in the slide, consisting possibly of an intergrowth of quartz and felspar, with some calcite, might represent a similar porphyritic mineral, or they are possibly amygdaloidal, like that figured by Mr. Phillips.[2] Sometimes associated with these, but distorted in form, are certain viridite or serpentinous strands, which may be examples of the crushed amygdaloids noted by Mr. Rutley, or possibly only the infilling of secondary cracks. They form the green films, which may be noticed on many of the schistose surfaces near Redlap, and in my specimens from that locality I searched in vain for any of the well-defined chlorite of the southern schists, with which mineral

[1] Q.J.G.S. 1886, vol. xlii. p. 393, pl. xii. figs. 1, 3.
[2] Q.J.G.S. 1878, vol. xxxiv. p. 483, pl. xx. fig. 2.

the rocks are said to be charged.[1] Mr. Somervail may, however, allude to some other specimens from these cliffs (since I did not attempt to make an exhaustive examination of the place). But, even if chlorite occurs, as it does, although not to a large extent, in the dyke further south, its presence is a rather slender argument for the identification of the schist and the diabase, since it is one of the commonest secondary products in basic igneous rocks of any age or locality.

I examined the associated sedimentary rocks at Redlap, and they are genuine phyllites of the ordinary Devonian character, with only the usual crystalline development of minute films along the lamination.[2] If the greenstones were the equivalents of the chlorite rock of the south, it would be strange, that these associated phyllites should present such wide and well-marked differences from the mica schists. They exhibit effects of pressure metamorphism, even more strongly than the phyllites just north of the fault, which bounds the crystalline series, and yet they are totally unlike the mica schists in that series. In one of the phyllites near Redlap, the laminæ are puckered up into undulations, across which at places extends a succession of small brown films. These appear to have formed from a ferruginous infiltration, inserting itself and accumulating between the laminæ, along the steeper slope of the waves. Just at this part, rupture has often taken place, thus forming an incipient strain-slip cleavage, marked only by a darker staining. The steeper slope of the undulations is almost universally in the same relative position —doubtless on that side towards which the thrust of the rocks was directed.

I must thank Mr. Somervail, for calling my attention to the deserted quarry of chlorite schist to the north of the Hall Sands streamlet, in consequence of which the boundary-line must be marked at that part of the valley as north of the stream.[3] It is to be regretted, however, that Mr. Somervail does not withdraw his former untenable assertion, but attempts to renew it, by confusing together the correct indication of the boundary given by Professor Bonney on the coast, and any slight modification which I have to make in the direction I traced inland. The position *on the coast* would not be affected by the occurrence of the chlorite schist south of the valley, nor by this chlorite schist north of the valley. The hypothesis of a straight east-to-west line for the fault is quite gratuitous, since no

[1] Trans. Devon Assoc. 1888, p. 224.

[2] Thus these rocks in the direction of their micaceous constituent would agree with the phyllites described by Professor Bonney from near Morlaix, Q.J.G.S. 1888, vol. xliv. p. 13, and would differ from those near Torcross, Q.J.G.S. 1884, vol. xl. p. 17.

[3] See map Q.J.G.S. 1887, vol. xliii. p. 715. The dotted line marking the junction of phyllites and metamorphic rocks should probably cross the stream about east of the *l* of Muckwell, before bending south-eastward or E.S.E. to the coast. This alteration does not, however, disprove the possibility that the fault may have determined the lower course of the valley, since there are no exposures which we can trust along the 400 yards between the quarry and the beach; and also in a continued erosion along a fault, a portion of one rock may often be left adhering at some spot to the mass against which it was faulted.

one attempts to draw such—how could the line in that case reach on the Salcombe estuary a position, which is considerably to the north of a line drawn due west from Hall Sands?

In connection, also, with the suggestion, that the chloritic rock near the fault-line was a "buffer, checking the northward spread of metamorphism,"[1] I should like to ask, why was this duty neglected by the much larger and more extensive mass near Prawle Point, and that overlooking The Barr?—to the northward of which, in both cases, lie well-marked mica-schists. I might take exception to many other statements, but I should not be justified in thus occupying space, for they are matters of detail, compared with the suggested identification of the two series of rocks. These may have some resemblance to each other—though I should have thought it so superficial as not to mislead any practised observer; but even if there be a vague resemblance, due to their having had the same origin, they cannot, as I have shown, have been manufactured at the same epoch.

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## VII.—On some Ostracoda from the Mabou Coal-field, Inverness Co., Cape Breton (Nova Scotia).

By Prof. T. Rupert Jones, F.R.S., and J. W. Kirkby, Esq.

THIRTEEN specimens of black shale, crowded with Ostracoda, besides fish-scales, Anthracomyæ (?), and other small fossils, were sent in 1886 by Mr. J. F. Whiteaves, F.G.S., Palæontologist of the Geological Survey of Canada, for examination. They had been collected by Mr. A. H. Foord, F.G.S., of that Survey, in 1881.

In these coal-shales the Ostracoda are very numerous as individuals, but belong apparently to very few species of one genus. They are in a great degree similar to those mentioned in the Geol. Mag. Dec. II. Vol. VIII. 1881, p. 95, and Dec. III. Vol. I. 1884, p. 358, etc., as occurring in the black coal-shales of the South Joggins, Nova Scotia.

In the Mabou coal-fields we find:—

1. *Carbonia fabulina*, J. and K., very abundant. It is of rather smaller size than the Scottish forms figured and described in the Ann. Mag. Nat. Hist. ser. 5, vol. iv. (1879), p. 31, pl. 2, figs. 1–10. The innumerable minute Ostracoda imbedded throughout the shale seem to be small individuals of *C. fabulina*.

2. Among the foregoing is a variety larger than the Scotch specimens referred to, rather more oblong in outline, and with stronger marginal overlap, and a somewhat coarser punctation of the surface. It may be termed var. *altilis* (well-nourished).

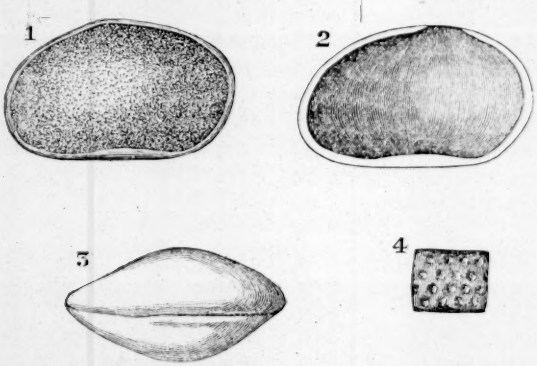
3. *Carbonia* (?) *bairdioides*, J. and K., also occurs, but far less abundantly than *C. fabulina*. The specimens more closely resemble fig. 24, pl. 3, "A. M. N. H." ser. 5, vol. iv. p. 38, than fig. 8, pl. 12 of the Geol. Mag., Dec. III. Vol. I. p. 359.

*Carbonia fabulina* is abundant in the Upper and the Lower Carboniferous formations of Britain, wherever the conditions had been

[1] Trans. Dev. Assoc. 1888, vol. xx. p. 217.

favourable for the formation of Coal-shales,[1] especially in the Lower Carboniferous series of Scotland. *C. bairdioides* occurs more rarely, but in strata similar to the above, in Scotland and Staffordshire. They both occur at the Joggins, on the shore of the Cumberland Basin, Cumberland Co., Nova Scotia, as noticed above.

The geological features of Inverness County (Cape Breton), Nova Scotia, and the relationships of the strata are described in detail in the Geological and Natural-History Survey of Canada: Report of Progress, 1885; and Reports and Maps of Investigations and Surveys, 1882–83–84; including Report (H) on the Geology of Northern Cape-Breton, by Hugh Fletcher, 1884.




Figs. 1–4. *Carbonia fabulina*, J. & K. Var. *altilis*, nov.

Fig. 1. Carapace, showing the left valve, overlapped by the other valve at the margin. × 25.

Fig. 2. Inside of the right valve. × 25.

Fig. 3. Dorsal view of the carapace. Not set quite upright, but sloping a little. × 25.

Fig. 4. Punctation of the surface; highly magnified.

The Inverness Coal-field is treated of at p. 53 H; and the Mabou Coal-basin at p. 61 H. This is referred to as belonging to the "Lower Carboniferous" series at p. 53 H and on the Map (No. 14, 1884), accompanying Mr. Fletcher's Report. At p. 6 of the Report H, however, it is referred to the "Middle Carboniferous," which consists of "Conglomerate and Coal-measures" in that locality.

The strata containing the specimens under notice are indicated in Mr. Fletcher's Map (No. 14) as at the place where Mr. Foord collected fossils in 1881, on the shore about one mile and a half south of Cape Mabou,[2] and about one mile north of the spot marked "Mabou Coal-mines" on the same map.

The "Black Shales" of the Mabou Coal-measures are mentioned in the list of strata at p. 70 H, thus—

"12. Dark-bluish-grey, thin-bedded, calcareo-bituminous shale;

[1] See Quart. Journ. Geol. Soc. vol. xxxv. 1879, pp. 30 and 38; and Geol. Mag. Dec. III. Vol. I. 1884, p. 360.

[2] The post-town called "Cape Mabou" is three miles east (inland) of Cape Mabou.

fish scales, teeth, coprolites, and spines, *Cythere*, *Naiadites*, *Spirorbis*. —2 feet.

"13. Dark-bluish-grey, flaggy, concretionary, calcareous rock, with the same fossils.—2 ft. 6 inches." There follow (14–29) other shales and shaley beds, more or less bituminous. At p. 71 H it is stated—"The black shales are those from which an interesting collection of fossils was made by Mr. Foord, of the Geological Survey, in the summer of 1881. In this collection the following forms have been determined by Mr. Whiteaves:—*Naiadites* (*Anthracoptera*) *carbonaria*, Dawson; *N.* (*Anthracomya*) *elongata*, Dawson; Entomostraca; *Rhizodus lancifer*, Newberry (scales); *Cœlacanthus* (jugular plates); scales of two genera of Ganoid Fishes; also jaws and teeth of Fishes undetermined."

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## VIII.—On the Discovery of *Turrilepas* in the Utica Formation (Ordovician) of Ottawa, Canada.

By Henry Woodward, LL.D., F.R.S., F.G.S.

MR. AMI'S interesting discovery has already been announced in a letter addressed to Mr. A. H. Foord, F.G.S., published in this Magazine (October, 1888). Mr. Ami now supplies a "Note" on the precise geological position of the beds in which the *Turrilepas* was found. Want of space, however, precludes us from giving the whole of his detailed observations, which are accompanied by a sketch section, here reproduced:—

The following is a summary of Mr. Ami's "Note."

The *Turrilepas* was found in a band of bituminous limestone cropping out on the right bank of the Rideau River, at the Rifle Range, near Ottawa. The precise position of the beds (Lower Utica = about the lower part of the Bala Series),[1] was ascertained by means of their fossil contents, which include an interesting Brachiopod—*Siphonotreta Scotica*, identified and named by the late Dr. T. Davidson, F.R.S.

The calcareous and shaly measures characterizing the Lower Utica in this district, as exposed on the Rideau River, have a south-by-west dip of about 4°, and exhibit a portion of the south-western limb of a low, denuded anticlinal, which, however, affects the physical aspect of the country to a very small extent.

The accompanying sketch is a diagram section of the rocks cropping out at the Rifle Range rapids. The depth of section is about 22 feet.

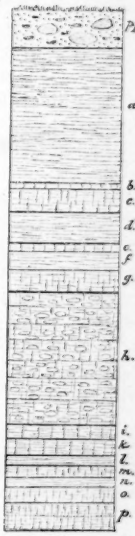



Diagram-section of rocks at Rifle Range near Ottawa.

[1] Mr. Ami regards them as equivalent to the Llandeilo of Craighead, Ayrshire.

(*pp.*) There are resting unconformably upon the Utica beds between 1 and 2 feet of Post-Tertiary sands and gravels, débris from the glacial clays or "till," the "Leda clay," and overlying sands of the Rideau Valley, a valley of denudation.

(*a.*) These upper measures consist of thin-bedded, soft, at times hardened, black or dark brown, bituminous shales, holding crinoidal fragments associated with *Lingula progne, Orthis testudinaria, Trocholites ammonius, Endoceras proteiforme, Triarthrus Becki, Asaphus Canadensis*, etc.

(*b.*) Thin *Conularia*-band, consisting of dark grey impure limestone, with *Orthis testudinaria, Leptæna sericea, Conularia Trentonensis*, etc.

(*c.*) Zone of *Siphonotreta scotica*, Davidson. Band of black bituminous limestone, often shaly in character, and containing numerous fossils, including *Lingula elongata, Discina Pelopea, Leptæna sericea, Zygospira Headi, Conularia Trentonensis, Calymene senaria, Beyrichia oculifera*, and *Turrilepas Canadensis*.

(*d, e, f, g.*) Thin bands of black, grey, or dark brown calcareous and bituminous shales, highly fossiliferous, except (*g*), which is "apparently destitute of fossils."

(*h.*) Light yellowish, grey weathering, argillaceous limestone bands, with shaly partings between the divisional planes of stratification, distinctly nodular in character and structure, disintegrating rapidly under atmospheric influence. Fossils:—*Monticuliporidæ*, Brachiopoda, Orthocerata, *Bucania expansa*. 5 feet 5 inches.

(*i, k, l.*) Thin bands of bituminous limestones and shales, from 3 to 10 inches in thickness, the last (*l*) holding *Orthis testudinaria, Leptæna sericea, Calymene senaria*.

(*m.*) Dark grey, bituminous, crinoidal limestone band with *Leptæna sericea*, etc. This stratum dips north and south, being on the axis of the anticlinal referred to above. Thickness varying from 4 to 6 inches.

(*n.*) Thin shaly parting, with *Asaphus Canadensis*.

(*o.*) Hard, compact, light-weathering, dark grey limestone band, holding *Orthis testudinaria, Leptæna sericea, Calymene senaria, Asaphus Canadensis, Conularia Trentonensis*.

(*p.*) Compact, dark grey, impure limestone, bituminous and fossiliferous, holding *Asaphus*, sp. indt., crinoidal fragments, etc., preserved in a light, yellowish-brown, ferruginous matrix. Thickness, 8 inches.

At a meeting of the Geological Society of London on June 7th, 1865, I described a new genus of Cirripedia from the Wenlock Limestone and Shale of Dudley, which I named *Turrilepas* (see Quart. Journ. Geol. Soc. vol. xxi. pp. 486–489, pl. xiv. figs. 1*a–l*).

This Cirripede (or part of a Cirripede) had as many as four rows of asymmetrical plates, with more than eight plates in each row; the surface of each plate had a uniform sculpturing of fine, slightly waving, delicate, raised lines similar to those seen on the opercular valves of *Balanus* or of *Pollicipes*. As many as three or four different

forms of plates are known, these are arranged in linear series of similar plates, each series being strongly imbricate from below upwards, and so disposed that the edges of the contiguous series are alternate in position, and partially cover one another laterally.

In the Supplement to vol. i. of Barrande's great work "Système Silurien du Centre de la Bohême," part i. 1872, p. 565, the author describes a similar form under the generic name *Plumulites*, of which he records ten species, based on detached plates from beds in various localities in Bohemia, from D 1=Lingula Flags, to E 2=Wenlock Limestone.

Several of these plates closely resemble those from the Wenlock Limestone of Dudley; the others, whilst agreeing in their ornamentation, have the apex of the plates obtuse, and the ornamental lines near the summit circular and fenestrated. These may possibly have been terminal or opercular plates, the more pointed forms being the peduncular plates (see Q. J. G. S. 1865, p. 488).

In their "Monograph of the Silurian Fossils of the Girvan District in Ayrshire," etc., H. A. Nicholson, and Robert Etheridge, jun. (vol. i. 1880, fasc. ii. pl. xiv. figs. 22–27, pp. 213–215, and fasc. iii. pp. 299–302, pl. xx. figs. 8–10) describe two new species of *Turrilepas*, namely, *T. Peachii*, Eth. and Nich., and *T. Scotica*, R. E., jun., from the Silurian of Girvan, Ayrshire.

In their observations on *Turrilepas* one of these authors writes (p. 213) as follows:—"The genus *Turrilepas* was established by Dr. H. Woodward for certain peculiar ovate-triangular plates from the Dudley Limestone, previously known under the name of *Chiton Wrightianus*, de Koninck. Dr. Woodward satisfactorily showed that these plates were more properly referable to a form of Cirripede allied to *Loricula* (and for which he proposed the name *Turrilepas*) than to *Chiton*, or to any other Mollusc.

"Priority is claimed by M. Barrande for his term (*Plumulites*) on the plea of previous publication. For my own part, I hardly think the facts support M. Barrande's claim. Dr. Woodward's name was both proposed and published in 1865; and although the genus was certainly not defined in so many words, it was nevertheless founded on a well-known and perfectly defined fossil, and, what is more, was copiously illustrated. I take this to be satisfactory publication. It appears that M. Barrande had discovered similar plates in the Silurian rocks of Bohemia, and applied to them the name *Plumulites*, —a fact which was communicated (orally) by Prof. Reuss to the Imperial Academy of Science of Vienna, 18th February, 1864, and the name was published in a paper of the latter,[1] but unaccompanied either by description or figure. So far as I understand the question, no description or figure was furnished by Barrande until the appearance in 1872 of the supplement to the first volume of his magnificent work on the Silurian System of Bohemia (already quoted).

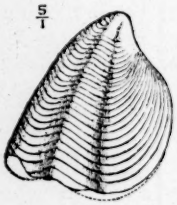
"I think, under these circumstances, that strict impartiality requires the adoption of Dr. Woodward's name *Turrilepas*. Again, Messrs. Hall and Whitfield adopt *Plumulites* in preference to

[1] Sitz. Berichte d. k. k. Akad. Wissensch. vol. xlix. p. 215.

*Turrilepas*, on the ground that the latter was never characterized; but my previous remarks equally apply in this case." (Nicholson and Etheridge, Girvan District, p. 214.)

In Messrs. James Hall and John M. Clarke's Geological Survey of the State of New York, Palæontology, Albany, N.Y. 1888 (4to. pp. 215–220, pl. xxxvi. figs. 1–19), the authors give figures and descriptions of eight species of *Turrilepas* from the Upper Helderberg and Hamilton groups=Devonian, Ontario and Ohio. One or two of these plates resemble somewhat Barrande's Bohemian species and also plates figured by the writer from the Wenlock Shale, Dudley, but they are apparently all specifically distinct from the European forms, but with the same persistent ornamentation in which they all agree.[1]

The discovery by Mr. Ami of a new specimen of *Turrilepas* in so low an horizon as the Utica series, equivalent to our Llandeilo Flags, is particularly interesting, as the species recorded by Messrs. Hall and Clarke in Ontario are all from the much later Devonian formation.




*Turrilepas Canadensis*, sp. nov., discovered by Mr. Ami in the Lower Utica series = Llandeilo, right bank of the Rideau River, Riffe Range, near Ottawa, Canada.

Description of the Ottawa specimen :—

Valve roughly triangular, right-hand border very broadly-rounded, but contracting inwards towards the apex; lower border sinuous in outline; left-hand margin nearly straight, curving slightly towards the apex, which is deflected a little towards the right side; the striæ, which are slightly raised, are about 30 in number, very delicate and regular, and all follow the undulations of the lower border; the carina dividing the right and left sides of the valve is very much nearer to the left-hand margin, with which it is also parallel nearly to the apex, the left side being only about one-third as wide as the right side; at about a third of the distance between the carina and the right-hand border of the valve and parallel to the carina is another *apparent* ridge (marked in the woodcut by a line of shading); this is really a flexure in the lines of growth and ornamentation, which is further emphasized by a fracture in the matrix containing the specimen exactly on this line.

The valve of *Turrilepas Canadensis* measures six millimetres in height and five millimetres in breadth.

In general form the Ottawa specimen agrees somewhat closely with

[1] This ornamentation, as I have pointed out (see GEOL. MAG. 1880, Dec. II. Vol. VII. p. 197) occurs also on the body-plates of the anomalous Cystidean, *Ateleocystites*, which is found in the same Wenlock Limestone of Dudley, and in the Trenton Limestone of Ottawa.

one of those figured by the writer in 1865 (see Quart. Journ. Geol. Soc. vol. xxi. pl. xiv. fig. 1*i*); but the Wenlock specimen is broader in proportion to its length, and the keel of the valve is straighter, and the general outline more angular than is the case with the Ottawa specimen.

I propose for this new form the trivial name of *Canadensis*, and trust that before long, through the researches of Mr. Ami, we may become aquainted with many more examples of the valves of this very interesting and widely-distributed fossil.

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## IX.—Remarks on Mr. Davison's Paper on Secular Straining of the Earth.

By Rev. O. Fisher, M.A., F.G.S.

A VERY important discovery was made independently by Mr. Davison, and somewhat earlier by Mr. T. Mellard Reade, when they demonstrated that, on the hypothesis of the earth having cooled as a solid body, there is within it a certain level, which is called by Mr. Davison the "surface of zero-strain," and for which Mr. Reade has adopted the term "level of no strain." At this level compression ceases, and for a certain distance beneath it extension, or stretching of the layers of the globe, takes the place of compression.

There are one or two points in Mr. Davison's paper which invite remark, because they have an important bearing upon the geological aspect of the subject. He states that he has come to the conclusion that, after an interval of 174,240,000 years since the earth solidified, the depth of the surface, or level, of no strain "was or more probably will be" five miles. But for geological purposes what we want to know is, what the depth of this level may be at the present time. Now, on the assumption that the earth has cooled as a solid, this is easily calculated, without the need of any knowledge either of the length of time since solidification, or of the conductivity of the materials of which the crust of the earth is composed.

The formula which gives the depth of the level of no strain within a few hundred feet is simple. It is:

$$\textit{Depth of level of no strain} = \frac{6}{3{\cdot}1416}\left(\frac{\textit{temperature of solidification}}{\textit{temperature gradient}}\right)^2 \div \textit{radius}.$$

The temperature gradient at present is known to be $\frac{1}{51}$ of a degree Fahr. per foot. The only quantity to be guessed at is the temperature of solidification, which Mr. Davison, following Sir Wm. Thomson, puts at 7000° Fahr. The radius of the earth in feet is 20,900,800.

Working out the sum we then find that the depth of the level of no strain, on this hypothesis respecting the temperature, is at the present time 11,645 feet, or 2·2 miles.

But 7000° Fahr. seems to be an excessive temperature for solidification; and if we put it at 4000°, which seems more probable, the depth of this level at the present time would only be a little over half a mile. It must be remembered that the depth of this level

increases as time goes on, so that it is deeper down now than ever it has been before.

It is obvious that the amount of compression which can be got out of a superficial shell certainly not more than two miles thick, and probably much less, the compression gradually diminishing and coming to an end at that depth, can have produced scarcely any appreciable folding. We must therefore look in some other direction for the cause of rock folding, thrust planes, and other phenomena of that nature. The probability is that the theory of the earth being solid throughout is incorrect.

## NOTICES OF MEMOIRS.

I.—Records of the Geological Survey of New South Wales. Vol. I. Part I. Department of Mines, Sydney, 1889. 8vo. 31 pp. and Plates i.—iv.

AS a significant indication of the increasing interest in geological science in New South Wales, it gives us pleasure to call attention to the first part of a new periodical, issued under the auspices of the Geological Survey of that colony, in which it is intended to record the discoveries and observations in the geology, palæontology and the mineral deposits of the country. The part just issued contains seven papers on a great variety of subjects, amongst which may be noticed 'Notes on the Geology of the Barrier Ranges District and Mount Browne and Tibooburra Goldfields, by C. S. Wilkinson, F.G.S., Geological Surveyor in charge'; 'Report on the Discovery of Human Remains in the Sand and Pumice Bed at Long Bay, near Botany,' by T. E. David, F.G.S., and Robt. Etheridge, jun., and 'On a Coral intermediate in structure between the Genera *Lonsdaleia* and *Spongophyllum*, etc.,' by R. Etheridge, jun.

G. J. H.

II.—Faune du Calcaire D'Erbray (Loire inférieure). Par Charles Barrois. Contribution à l'étude du Terrain Dévonien de l'Ouest de la France. Extrait des Mémoires de la Société géologique du Nord, tome iii. Avril, 1889. pp. 384, pls. i.-xvii.

FROM the beds of limestone quarried near the small town of Erbray (Loire inférieure) a comparatively rich fauna was obtained by M. Cailliaud in 1861, who compared it with that of the Bohemian étage F., the so-called third Silurian Fauna of Barrande, and it has since been regarded as the sole representative of this particular division in France. This conclusion is now called in question by Dr. C. Barrois, who has made an exhaustive study of the fossils from these rocks, and described and illustrated them very fully in the present memoir. The limestones yielding the fossils occur as discontinuous lenticular masses in a series of fine argillaceous schists, which are unfossiliferous and estimated to be from 800 to 1000 mètres in thickness. Dr. Barrois recognizes three distinct levels in the limestones, each marked by particular litho-

logical characters, corresponding to as many palæontological zones. Some of the beds are largely crinoidal; the fauna on the whole is very varied, and the number of species described is about 200, of which 57 are considered as new. Amongst the corals simple forms of *Cyathophyllum*, *Zaphrentis* and *Amplexus* predominate. A new genus, *Briantia*, is proposed for simple corals allied to *Cyathophyllum*, but with a solid external zone of considerable width. New species of *Striatopora*, *Cœnites*, and *Acervularia* are likewise described; *Heliolites*, *Favosites*, *Beaumontia*, and *Alveolites* are also represented, but no forms of *Stromatopora* have been recognized. The Brachiopoda are very numerous; the principal genera are *Rhynchonella*, with two new species; *Orthis*, *Meristella*, *Athyris*, *Spirifer*, and *Centronella*? each with three new species; examples of *Strophomena*, *Atrypa* and *Pentamerus* are also present. Of the Lamellibranchs, the genus *Conocardium* is the most numerously represented. The Gasteropods all belong to the Holostoma, the principal forms are included in the genera *Pleurotomaria*, *Murchisonia*, *Bellerophon*, *Strophostylus*, and especially *Platyceras*, of which there are no fewer than 12 new species. The Cephalopods are mostly included in the subgenus *Jovellania*, and the Trilobites belong to *Calymene*, *Phacops*, *Dalmanites*, *Proetus*, *Harpes*, *Cheirurus* and *Bronteus*.

The fauna of the Erbray limestones bears a great resemblance to the Hercynian fauna of the Harz, and to that of the Étages F. G. H. of Barrande. It is referred by the author to the Étage Gedinnian, which is at the base of the Devonian in the West of Europe, and it likewise corresponds to the Oriskany sandstone and the Upper Helderberg of North America and the limestones of the Carinthian Alps and of the Urals. It is a distinctly lower stage than that of the Coblenzian, which by many authors is still regarded as the base of the Devonian. G. J. H.

## REVIEWS.

### I.—The Probable Cause of the Displacement of Beach-lines. An Attempt to Compute Geological Epochs. By A. Blytt.

[*Printed in English*, Christiania Videnskabs-Selskabs Forhandlinger, 1889, No. 1. With two Supplementary Notes.]

ON first thoughts it seems impossible to divine any connection between layers of septaria or bands of ironstone, and the eccentricity of the earth's orbit. Yet those who have read with attention a previous communication by the same author, "On Variations of Climate in the Course of Time,"[1] will perhaps not be surprised at the latest evolution of his doctrines.

A study of the Recent and Post-Pliocene deposits of Norway and Denmark furnished the author with evidence "that climate is subject to periodical alterations." He was also led to conclude that alter-

[1] Reprinted in "Nature," July 8th and 13th, 1886.

nations of strata, formed under different physical conditions, could not, as a rule, be attributed to local phenomena, but are rather due to general and more permanent causes.

Thus in cold and dry periods, the rivers which are nourished mainly by springs, are rich in soluble substances, and from their comparatively small volume, they carry little detrital matter. In rainy periods, the rivers, then poor in soluble matter, transport much clay, sand, and gravel. Hence dry periods should be marked by chemical deposits; rainy periods by mechanically-formed sediment.

Admitting that layers formed chemically and mechanically will be accumulated at all times, the author observes that they will be deposited in different places according to the variable amount of rainfall. When, however, clay alternates with limestone; when thick beds of sand alternate with sandstone cemented chemically by salts of iron and lime, or by silica: when clay alternates with layers of septaria, etc.: then (in the author's opinion) do the first-named beds date from periods with warmer ocean-waters and greater rainfall, than attend the formation of the latter.

The author is indeed unfortunate in his examples. If he had omitted all mention of septaria, which were formed since the deposition of the strata in which they are embedded, and which frequently enclose organisms identical with those found in the clay above and below them; and if he had taken no notice of sands which may be hardened by chemical agency long subsequent to original deposition, and which indeed are compacted at various horizons—then indeed we might pass on to consider his general conclusions with less misgiving than we do now; but our faith in his geological knowledge is sorely tried.

Other alternations of strata are considered to be due to "a rise and fall of the sea in relation to the land," the result being "an alternation of deep-sea formations with littoral formations or fresh-water beds."

Of the two explanations thus given of alternations of strata, both causes in the author's opinion are periodically active. In the one case climatic causes are repeated at somewhat regular intervals; in the other, the changes in the relative level of land and water are repeated at longer and less regular intervals.

Periodical variations of climate, explained by comparatively small fluctuations in the extremes of temperature and rainfall, are attributed to periodical changes in the strength of ocean-currents. From ocean-currents the author turns to prevailing winds, to changes in atmospheric pressure, and finally to the precession of the equinoxes and the eccentricity of the earth's orbit as originating periodical variations of climate.

Thus alternately in the northern and southern hemispheres, the precession of the equinoxes causes the summer to be, for about 10,500 years, longer than the winter, but in the subsequent 10,500 years to be shorter. The author considers that although the periodical changes of climate were not great, yet they were sufficient to imprint themselves on the strata, in the alternation of

beds, and in the formation of beach-lines, terraces, and moraines. To each period of precession there corresponds one alternation of strata.

In order to illustrate this portion of the subject, the author institutes a comparison between astronomical periods and the different series of geological strata. We may pass briefly over this portion of the subject. Suffice it to say that calculations have been made of the curves of the eccentricity of the earth's orbit. These curves or fluctuations are repeated once in about every $1\frac{1}{2}$ million years. The eccentricity has been calculated for a period of $4\frac{1}{2}$ million years, with the result that three curves are indicated. In each of these cycles of $1\frac{1}{2}$ million years, the author finds 16 arcs of the curve, which correspond with certain oscillations in the eccentricity of the earth's orbit.

The change in the tidal-wave caused by the variation of the eccentricity is presumed to be sufficiently great to explain the displacement of beach-lines. Each arc of the curve before mentioned corresponds to one oscillation of the sea. For every considerable oscillation of the beach-lines there is a corresponding geological stage. In these stages there will be found a certain number of alternations of strata, as many in fact as there are periods of procession in the corresponding arc.

The author remarks that the oscillation of beach-lines, corresponding to an arc, cannot be pointed out everywhere, but only in those geological basins where the forces at the time exerted their effect. In the Hampshire and Paris Basins he finds the total number of alternations in the strata to be about the same; and he endeavours to illustrate this by noting the number of alternations he finds in the different subdivisions of the Tertiary strata. One quotation will suffice to illustrate the method of the author. He remarks:—"The Upper Eocene Barton Clay has 5 layers of septaria. It is synchronous with the Grès de Beauchamp of the Paris basin, and it must consequently, like this, correspond to the arc 14 of the curve. This arc represents 100,000 years, and, consequently, about 5 periods of precession."

We must confess our utter disagreement with the author in his interpretation of geological facts.

As before mentioned, septaria afford no clue to changes in the physical conditions attending deposition. Again, the author remarks that "between the Eocene and the Oligocene a great break exists in the Isle of Wight," and he proceeds to remark that this may represent about 200,000 years. Now as a matter of fact there is no physical break between these divisions in the Isle of Wight. Moreover, the Tertiary strata are for the most part so variable in character, that it is not always possible to correlate particular layers exposed in the cliffs on the east side of the island with those seen on the west. What, then, is the value of the author's contention that the Eocene period appears to have had 16 oscillations, and should correspond to the first cycle, extending from 3,250,000 till 1,810,000 years before the present time? We fear the only verdict that can be given is,

that the author's conclusions are of no geological value. At the same time we can but admire his enthusiasm, and admit that many of his remarks are exceedingly suggestive.

We have yet to consider the author's views of the "rise and fall of the sea in relation to the land." While he believes that beach-lines oscillate periodically backwards and forwards, he accepts the view that the great ocean depths and the great continents have, in all essential respects, retained their original relations to each other from the remotest times. When, however, he comes to discuss the form of the earth and the possible changes it has undergone, he finds that the cooling and contraction of the body of the globe are insufficient to account for all the phenomena. He believes that the lengthening of the sidereal day has had much influence on the form of the solid globe. The tidal wave which rises and falls, in some measure, with the eccentricity of the earth's orbit, is considered the most powerful agent in altering the sidereal day and in lengthening it; and as the centrifugal force diminishes during the lengthening of the sidereal day by tidal friction, strain accumulates in the solid earth, until the limit of resistance is reached. Hence arose vertical displacements of beach-lines.

The author remarks that most earthquakes are caused by dislocations, and that in countries where the inner strain has been relieved by great displacements in recent periods, earthquakes will probably be rare, and less destructive than in countries where there is still a great strain in reserve. Thus he concludes that great upheavals and subsidences are caused by strains, which have accumulated through very long periods.

He considers that the shore-lines in higher latitudes may be brought to recede, either by the rising of the land in the same region, or by the subsidence of the sea-bottom in lower latitudes. During the Tertiary period each oscillation did not exceed a few metres. Those who desire fully to understand the arguments of the author must consult his papers. For our own part we feel that very many of the geological facts to which he appeals lend no real support to his hypotheses; and that while his contention that precession has left its imprints on the strata is in itself plausible, yet the particular conclusions he draws on the means of measuring geological time rest on too oscillating a foundation to have any permanent value.

H. B. W.

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II.—Die Stämme des Thierreiches; von M. Neumayr. Wirbellose Thiere. Erster Band, mit 192 Textbildern. Royal 8vo. pp. 603. (Wien u. Prag, Tempsky, 1889.)

THE aim of this work is to trace out the descent-relationship of the various forms of animal life so far as they can be ascertained from geological and palæontological sources. Firmly impressed with the idea that the Darwinian theory of descent affords a reasonable interpretation of the phenomena of the succession of life as shown in the rocks, Prof. Neumayr set before himself the arduous task of working out the history and relationships of

each of the divisions of the animal kingdom from its first appearance in the geological series, through each successive stage, until its extinction or its continuance in the organisms still existent, with the view of representing in one work the different steps in the course of its development. It is, in reality, an attempt to co-ordinate the facts of palæontology with the theory of descent in the same way as has been successfully done with those of embryology and comparative anatomy.

In an introductory chapter, the nature of the evidence to be derived from palæontology, and its application to the theory of descent, are treated at considerable length. In contrast to that afforded by the study of living organisms, in which every structural detail can be determined, only the hard parts of fossils have been preserved, and these often in scattered fragments, with their original condition modified in varying degrees by fossilization, so that satisfactory conclusions as to the characters of fossil organisms can only be made by those investigators who, in addition to a thorough knowledge of the anatomy and development of existing animals, have acquired experience in interpreting the relations of mere fragments, and these often masked and distorted. The difficulties are also increased by the fact of the important differences between existing and extinct forms of life, the greater in proportion as we go back in time; and as some of the oldest forms differ altogether from any now existing, their characters must always remain enigmatical.

It cannot be said that we have any satisfactory knowledge of the *beginnings* of life from the facts of palæontology. In the oldest known fossiliferous rocks of the Cambrian period there is already a great variety of different forms of life; and if these really represented the oldest types, it would be strong evidence against the theory of descent. We can only suppose that long before Cambrian times, organic life may have existed through immeasurable periods of time, and this supposition is supported by the presence of graphite, anthracite, bitumen, and limestones—substances which are regarded as having an organic derivation—in the Archæan rocks. The form known as *Eozoon*, however, is of too doubtful a character to be accepted as a proof of organic life.

Not only are the earliest types of organic life missing, but throughout the geological series there are undoubtedly great gaps in the succession. The number of species in the existing animal kingdom approaches to 300,000, whilst there are only from 70,000 to 80,000 fossil species. This great preponderance of existing forms is largely owing to the number of insect species, which constitute three-fourths of the total, whilst they are relatively rare as fossils. Of organisms inhabiting water, there are more fossil species known than recent; but, on the other hand, the existing species of land-dwellers are more numerous than those preserved as fossil. As an indication of the vast army of forms which in all probability have been wholly obliterated from our knowledge, the author states that there is good evidence to show that the marine life of the Jurassic seas was as various and abundant as that now existing; that during

this period more than thirty distinct zones, each with its own peculiar fauna, can be distinguished; and making sufficient allowance for forms common to more than a single zone, the number of species which may have existed during the whole Jurassic period can hardly have been fewer than from 500,000 to 750,000. And yet the total number of marine fossil species from all the Jurassic beds only mount up to about 10,000, a very insignificant proportion in comparison with the above estimate. If such deficiencies exist where the geological series is fairly continuous, still greater ones may be presumed where there are breaks in the succession like those between the Tertiary and Mesozoic, and the Mesozoic and Palæozoic groups.

In view of the above it is useless to expect that a complete succession of fossils could be found in which all the varieties intermediate between different species were represented; but nevertheless fairly distinct lines of descent can be shown in the case of certain Brachiopods, Corals and Crinoids from the Palæozoic strata; in the Mesozoic Ammonites and the Molluscan genera *Pholadomya*, *Inoceramus* and *Halobia*, and in many Tertiary forms. As good examples of a gradually changing series of forms may be cited the fresh-water *Paludinas* from the Lower Pliocene of Sclavonia, in which the individuals at the beginning vary so much from those of the higher end of the series, that they might be taken for distinct genera if it were not for the numerous intermediate connecting forms.

The causes which have led to the extinction of species are to the palæontologist of as great interest as those relating to their origin. A great number of species have become extinct in historical times, some mainly through man's influence. It can hardly be said that species become extinct because they have outlived their capacity to vary, for we find still existing genera, such as *Rhynchonella*, *Lingula*, and *Discina*, which have varied but very little since their first appearance in the Palæozoic era; whilst on the other hand such forms as *Ammonites* and *Rudistes* exhibit remarkable variations shortly before they became extinct. The complete extinction of many groups of organisms which existed through long geological periods in great numbers and in manifold variety, as, for instance, the Trilobites, is difficult to account for; but there is nothing to support the theory that this or any other group of animals inhabiting widely-separated localities became contemporaneously extinct; for so far as it can be traced, the extinction of a species is not sudden, but rather a gradual process. In certain instances it is possible to connect the disappearance of a predominant group with the gradual increase and subsequent supremacy of another group which thus supplants it, and furnishes an instance of the 'survival of the fittest'; but in other cases, such as the Carboniferous *Fusulina* and the Tertiary *Nummulites*, there is no evidence of extinction from such a cause.

The next five chapters of the work are devoted to the consideration of the following invertebrate groups: I. Protozoa; II. Cœlenterata; III. Echinodermata; IV. Annelida; and V. Molluscoidea. As a preliminary introduction to each group, the most important of its structural details are given with figures of the typical forms.

Protozoa.—In this group are included the Foraminifera and Radiolaria. As regards the former, the author points out the comparative scarcity of their remains in the older Palæozoic rocks and their comparatively sudden appearance in great variety in Carboniferous strata, in which some highly organized forms, as *Nummulites*, *Fusulina*, etc., are associated with *Nodosaria*, *Textularia* and *Astrorhizida*, etc. The forms with calcareous shells are all regarded as derived from those with agglutinated tests, and these again have probably sprung from types with extremely simple and irregular tests like those of the Astrorhizidæ.

In the brief notice given of the Radiolaria, it is mentioned that the forms recently discovered in Jurassic and Triassic strata show but small differences from those of Tertiary and recent seas, and afford no clue to the natural relationships of the various divisions.

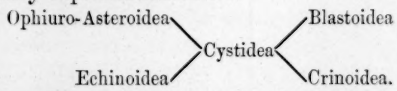
In the Cœlenterate division are embraced the Sponges, Corals, Hydrozoa, and Graptolites. As regards the Sponges, the author adopts with certain modifications the views of Zittel, and concludes with diffidence that the siliceous forms are probably derived from some more ancient type, in which the elementary spicule of the skeleton was irregularly polyaxile.

The Corals are treated very fully, and due importance is given to the fresh light thrown upon their characters by the microscopic observations of recent students. The Rugosa or Tetracorallia are regarded as a sharply defined group characterized by the symmetrically bilateral arrangement of their septa, and they are believed to be restricted to Palæozoic strata. Attempts are made to show that the forms from Mesozoic rocks which have been relegated to this group do not really belong to it, and conversely that Palæozoic Corals which have been placed with the Hexacorallia should really be included with the Rugosa. Some of the statements respecting the sharp division between the Rugosa and the so-termed Hexacorallia, namely, that the young forms of the former group are always symmetrically bilateral, and that in the latter the septal skeleton is purely radial and at the commencement with six septa, are too comprehensive and can hardly be substantiated. The genus *Calostylis* from Silurian strata, which, by Lindström, Nicholson and other excellent observers, is considered to be an undoubted member of the Perforata, is cast out of this division by Neumayr on the suspicion that it possesses bilateral symmetry, and that it is thus a Perforate Rugose Coral; but it is probable that the objection to ranking it with the normal Perforate Corals mainly depends on its occurrence in the Palæozoic rocks. The Palæozoic Favositoid Corals are regarded as forming an independent group, on the ground that the perforations in their walls are morphologically entirely different from those in normal Perforate Corals, and we think the objection a good one. The genera *Heliolites* and *Halysites* are, on the grounds of their possessing twelve true septa, indicating a corresponding number of true mesenteries and tentacles, considered as nearly related to the Fistuliporidæ and without any real affinity to the Alcyonarian genus *Heliopora*, with which they have been associated

by Moseley and subsequent authors. Neumayr concludes that the great mass of the Palæozoic Tabulate Corals, distinguished as Favositidæ, Chætetidæ and Heliolitidæ, form a natural group, whose individual members are connected by intermediate forms. The relations between these Tabulate and the other leading groups of the Rugosa and the Hexacorallia cannot, in the present state of our knowledge, be determined.

The descriptions given by Nicholson of the structure and relations of the Stromatoporoidea are adopted by Neumayr. The true position of the Graptolites is regarded as doubtful; whilst some of their structural features indicate relationship to certain Hydrozoa, others point to a connection with Bryozoa, and the possibility is not excluded that they form an extinct group which has left no descendants.

The Echinodermata are very fully treated, and the structural features which link together the members of each of its divisions are carefully traced. There are, however, no indications in the fossil forms of the kind of animal from which the class has been developed. The Cystoidea are considered to be the central group from which connecting threads of relationship run to the other orders. The Sea-urchins are connected through *Cystocidaris*, and the Sea-stars through *Palæodiscus*, with those Cystideans whose test is irregular, and consists of numerous plates; whilst the Cystideans, with a test of a small number of fairly regular plates, approach the Crinoids through *Porocrinus* and *Hybocystites*, and the Blastoids through *Codonaster* and *Asteroblastus*. The relation between the groups may be graphically represented thus:




The Annelids or Worms, though so important a group zoologically in the consideration of the theory of descent, are but little adapted for preservation in the fossil state, and the traces they have left in the rocks throw scarcely any light on the characters of the early types. With regard to the genus *Tentaculites*, Neumayr states that probably it belongs to the Tubicola, and that there is not the slightest ground for ranging it with the Pteropoda.

The last division treated in the present volume is the Brachiopoda, in which a new arrangement is proposed varying in many respects from that at present adopted. In this the two main divisions are named Ecardines and Testicardines, corresponding generally to the Inarticulata and the Articulata. The Testicardines are subdivided into Eleuterobranchiata, without calcified free arm-supports, and Pegmatobranchiata, with free arm-supports. Forms in which the arm-supports consist of a loop, or of two free lamellæ only, are grouped as Campylopegmata, and those in which the supports are the well-known conical spirals, as Helicopegmata. Whilst it is possible to indicate the descent-relationships between many of the members of each subdivision, there is much uncertainty as to the relationship between these groups, and forms like *Atrypa* and *Retzia* may prove to be nearer related to *Rhynchonella* and *Wald-*

*heimia* respectively than to the other members of the Helicopegmata with which they are included.

The above notes afford but a very imperfect indication of the contents of this work, which is destined to exercise considerable influence in the advance of the science of palæontology. It is very generally thought that this science embraces nothing beyond dry descriptions of fossil species, but Prof. Neumayr shows that these are but the raw materials which, in skilled hands, yield conclusions of far-reaching interest and importance. It has been inevitable that the early stages of the science should have been devoted to the accumulation of the raw materials for future use; but in going over the pages of this work, we yet find numerous reminders of the deficiency in this respect. Much of the elementary work of the past has been of too superficial a character to be of service in solving such problems as that of descent; but there is every prospect that the more thorough modes of investigation, by means of thin sections and the microscope, which palæontologists now adopt, will in time clear up many of the difficulties which have confronted Prof. Neumayr in his present task.

## REPORTS AND PROCEEDINGS.

### Geological Society of London.

I.—April 17, 1889.—W. T. Blanford, LL.D., F.R.S., President, in the Chair.—The following communications were read:—

1. "On the Production of Secondary Minerals at Shear-zones in the Crystalline Rocks of the Malvern Hills." By Charles Callaway, Esq., M.A., D.Sc., F.G.S.

In a previous communication the author had contended that many of the schists of the Malvern Hills were of igneous origin. Thus, mica-gneiss had been formed from granite, hornblende-gneiss from diorite, mica-schist from felsite, and injection-schists from veined complexes which had been subjected to compression. As a further instalment towards the elucidation of the genesis of the Malvern schists, it was now proposed to discuss the changes which the respective minerals of the massive rocks had undergone in the process of schist-making.

The schistosity was usually in zones, striking obliquely across the ridge, varying in breadth from a few inches to many yards, and separated from each other by very irregular intervals. Within the zones bands of maximum schistosity alternated with seams in which the original structure had been less completely obliterated. The new structure was connected with a shearing movement, by which the rigid mass was often sliced into countless parallel laminæ or flakes. In a more advanced stage of alteration, the planes of movement were obliterated, and a sound clear gneiss or schist was formed. These foliated bands were called "shear-zones."

The most important shear-zones were those in which diorite was interlaced with granite-veins. The following changes were noticed in tracing the massive rocks into the zones. The hornblende might suffer excessive corrosion, or it might become "reedy" and break

up along the cleavages into numerous fragments, which were drawn away from each other in the direction of foliation, or might pass into chlorite, or chlorite and epidote. The chlorite thus formed often passed into biotite, and sometimes the biotite was changed to white mica. Where shearing was excessive, chlorite sometimes passed directly into white mica.

Soda-lime felspar was altered to epidote or zoisite, and often to calcite. A more important result was the production of muscovite in the plagioclase. Much of this felspar was reconstructed in small clear crystals or granules. Quartz also was abundantly produced. Diorite might thus be converted either into a gneiss with two micas, or into a gneissoid quartzite. The granite of the veins passed through the usual changes in muscovite-gneiss.

Other secondary minerals were actinolite (from augite), sphene (from ilmenite), and garnet.

It was contended that the granite-veins were exogenous, because they appeared as apophyses from large masses, they had the same coarse texture in different varieties of diorite, and they produced contact-effects similar to those of intrusive veins, including the phenomena of aggregation and enlargement in the minerals of the encasing rock.

Foreign minerals were often introduced by infiltration. Thus, the hornblende of a diorite was decomposed into chlorite and iron-oxide, which passed for a considerable distance along the shear-planes of an adjacent granite, giving rise to a chlorite-gneiss, and the chlorite was partially changed to biotite. Epidote might be introduced in the same way.

Both the diorite and the granite of shear-zones tended by loss of bases to become progressively silicified. Most of the liberated bases could be accounted for. Analyses showed there was an interchange of alkaline bases, soda going to the granite, and potash to the diorite. Thus, some of the latter contained almost twice as much potash as soda.

The evidence collected seemed to prove that the schist-making had taken place subsequently to consolidation; but it was clear, especially where the rock was heavily sheared, that the constituents had been re-dissolved and reconstructed. Thus, as we followed a diorite into the core of a shear-zone, we could see the gradual disappearance of shear-planes and other mechanical effects, as well as the progressive results of chemical synthesis.

The secondary origin of the micas and of part of the felspar was proved by the fact that they were moulded on decomposition-products, such as chlorite and epidote, and upon fragments of hornblende crystals, which had been crushed during the shearing, and carried away from each other. The mineral changes as here described resulted from contact-action *plus* mechanical force.

2. "The Northern Slopes of Cader Idris." By Grenville A. J. Cole, Esq., F.G.S., and A. V. Jennings, Esq., F.L.S.

From the publication of Mr. Aikin's paper in the Transactions of the Geological Survey in 1829 to the second edition of the Survey Memoir on North Wales, the relations of the geological and physical features of Cader Idris have been pointed out in some detail. The

present paper dealt with the nature of the eruptions that took place in this area and the characters of their products at successive stratigraphical horizons. The best exposures occur, as is well known, upon the northern slopes.

The lowest evidence of contemporaneous volcanic activity is to be found at the Penrhyn-gwyn slate-quarry, where a somewhat coarse bed of tuff, with slate-fragments and abundant felspar-crystals, occurs above an andesitic sheet. Similar slate-tuffs are repeated up to the base of the great cliff of Cader Idris, with intervening layers of normal clayey sediment. On the whole, the tuffs and ashes become more highly silicated as the upper levels are reached, and they terminate on the southern slopes in beds with fragments of perlitic and devitrified obsidian, such as are found under Craig-y Llam. On Mynydd-y-Gader the intrusive dolerites have altered the ashes into hornstones; in places, moreover, they have become jointed into distinct columns. Fragments of andesitic glass as well as trachyte are recorded.

The "pisolitic iron-ore" of the Arenig beds appears to have resulted from the metamorphism of an oolitic limestone, as in the case of the Cleveland ore described by Mr. Sorby, and that of Northampton described by Prof. Judd. The grains still give evidence under crossed Nicols of their having been built up of successively deposited concentric layers. The calcite so freely developed in the hollows of the underlying rocks may have been largely derived, during metamorphic action, from the destruction of similar thin limestone seams. No true lava-flows occur among these tuffs and sediments, a fact that implies comparative remoteness from the volcanic centre; and the important masses of intrusive matter represented upon the maps are themselves largely composed of the products of explosive action. The numerous sheets of ophitic dolerite, aphanite, and altered andesite, that lie, seemingly interbedded, on the northern slopes, were probably intruded when the associated rocks were already weighed down by much superincumbent sediment. A common character of these basic sheets is the development of small colourless crystals of epidote.

The most striking mass upon the mountain is the main "felstone" (eurite) of the wall, which proves to be minutely "granophyric," and of very uniform grain throughout. An analysis by Mr. T. H. Holland shows 73 per cent. of silica. This vast intrusive sheet is regarded as perhaps of no later date than the Llandeilo lavas of Craig-y-Llam, and as a forerunner of the volcanic conditions that prevailed in Bala times throughout North Wales.

The stratigraphical horizons, as shown on published sections, would throw a great part of the tuffs and ashes described into the Tremadoc beds, or even lower, in contradiction to the generally accepted statement that volcanic activity began in Arenig times. While this point can only be settled by detailed mapping on the basis of the new six-inch survey, the authors incline to the belief that the eruptions in this area broke out in the Cambrian rather than the Ordovician period.